SEDAR

SouthEast Data, Assessment, and Review

SEDAR 9

Stock Assessment Report 1

Gulf of Mexico

Gray Triggerfish

SECTION 3. Assessment Workshop

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1. Introduction

1.1. Workshop Time and Place

The SEDAR 9 Assessment Workshop was held in Miami, FL, August 22 – 26, 2005.

A follow-up Assessment Workshop was held in Atlanta, GA, December 19-20, 2005

1.2. Terms of Reference

1. Select several appropriate modeling approaches, based on available data sources, parameters and values required to manage the stock, and recommendations of the Data Workshop.
2. Provide justification for the chosen data sources and for any deviations from Data Workshop recommendations.
3. Estimate stock parameters (fishing mortality, abundance, biomass, selectivity, stock-recruitment relationship, etc); include appropriate and representative measures of precision for parameter estimates and measures of model 'goodness of fit'.
4. Characterize uncertainty in the assessment, considering components such as input data, modeling approach, and model configuration.
5. Provide yield-per-recruit and stock-recruitment analyses.
6. Provide complete SFA criteria. This may include evaluating existing SFA benchmarks or estimating alternative SFA benchmarks (SFA benchmarks include MSY, Fmsy, Bmsy, MSST, and MFMT). Develop stock control rules.
7. Provide declarations of stock status relative to SFA benchmarks: MSY, Fmsy, Bmsy, MSST, MFMT.
8. Estimate Allowable Biological Catch (ABC) and provide an appropriate confidence interval.
9. Project future stock conditions and develop rebuilding schedules if warranted; include estimated generation time. Projections shall be developed in accordance with the following:

    A) If stock is overfished:
    F=0, F=current, F=Fmsy, Ftarget (OY),

    F=Frebuild (max that rebuild in allowed time)

    B) If stock is overfishing

    F=Fcurrent, F=Fmsy, F= Ftarget (OY)

    C) If stock is neither overfished nor overfishing

    F=Fcurrent, F=Fmsy, F=Ftarget (OY)

10. Evaluate the results of past management actions and probable impacts of current management actions with emphasis on determining progress toward stated management goals.
11. Provide recommendations for future research and data collection (field and assessment); be as specific as practicable in describing sampling design and sampling intensity. Prioritize recommendations based on their likelihood for improving stock assessment.

12. Fully document all activities: Draft Section III of the SEDAR Stock Assessment Report and provide complete tables of estimated values.
    Reports are to be finalized and distributed to the panel for review by September 30.
    Comments due to editors by October 14.
    Final version due to Coordinator by October 28.

1.3. List of Participants

1.3.1 Assessment Workshop I, August 22-26 2005

Workshop Participants:

Harry Blanchet .... LA DWF/ GMFMC FSAP
Liz Brooks .... NMFS/SEFSC Miami, FL
Craig Brown .... NMFS/SEFSC Miami, FL
Shannon Calay .... NMFS/SEFSC Miami, FL
Guillermo Diaz .... NMFS/SEFSC Miami, FL
Bob Dixon .... NMFS/SEFSC Beaufort, NC
Bob Gill .... GMFMC Advisory Panel
George Guillen .... Univ. Houston/GMFMC SSC
David Hanisko .... NMFS/SEFSC, Pascagoula MS
Walter Ingram .... NMFS/SEFSC Pascagoula MS
Bob Muller .... FL FWCC/GMFMC SSC
Debra Murie .... University of Florida/GMFMC FSAP
Josh Sladek Nowlis .... NMFS/SEFSC Miami, FL
Scott Nichols .... NMFS/SEFSC Pascagoula MS
Dennis O'Hern .... GMFMC Advisory Panel
Larry Perruso .... NMFS/SEFSC Pascagoula MS
Steven Saul .... RSMAS/ SEFSC Miami FL
Jerry Scott .... NMFS/SEFSC Miami, FL
Steve Turner .... NMFS/SEFSC Miami, FL

Observers:

Kay Williams .... GMFMC
Elizabeth Fetherston .... Ocean Conservancy
Albert Jones .... .GMFMC SSC

Staff:

John Carmichael .... SEDAR
Stu Kennedy .... GMFMC
Dawn Aring .... GMFMC
Patrick Gilles .... NMFS/SEFSC Miami FL

1.3.2 Assessment Workshop II, December 19-20 2005

Workshop Participants:

Liz Brooks .... NMFS/SEFSC Miami, FL
Craig Brown .... NMFS/SEFSC Miami, FL

Shannon Calay .... NMFS/SEFSC Miami, FL
Guillermo Diaz.. NMFS/SEFSC Miami, FL
George Guillen.. Univ. Houston/GMFMC SSC
Walter Ingram .... NMFS/SEFSC Pascagoula MS
Bob Muller .... FL FWCC/GMFMC SSC
Debra Murie .... University of Florida/GMFMC FSAP
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Jerry Scott .... NMFS/SEFSC Miami, FL
Steve Turner... NMFS/SEFSC Miami, FL

Observers:

Roy Williams .... GMFMC

Staff:

John Carmichael.. SEDAR
Stu Kennedy.. GMFMC
Dawn Aring... GMFMC
Patrick Gilles... NMFS/SEFSC Miami FL

1.4. List of Assessment Workshop Working Papers, Assessment Workshop I & II

SEDAR9-AW1	Incorporating age information into SEAMAP trawl indices for SEDAR9 species	Nicholls, S.
SEDAR9-AW2	Separating Vermilion Snapper Trawl Indexes into East and West Components	Nicholls, S
SEDAR9-AW3	Modeling Shrimp Fleet Bycatch for the SEDAR9 Assessments	Nicholls, S
SEDAR9-AW4	Status of the Vermilion Snapper (*Rhomboplites Aurorubens)* Fisheries of the Gulf of Mexico	Cass-Calay, S.
SEDAR9-AW5	Gulf of Mexico Greater Amberjack Stock Assessment	Diaz, Guillermo A., and Elizabeth Brooks
SEDAR9-AW6	A Categorical Approach to Modeling Catch at Age for Various Sectors of the Gray Triggerfish (*Balistes Capriscus)* Fishery in the Gulf of Mexico	Saul, Steven and G. Walter Ingram, Jr.
SEDAR9-AW7	Updated Fishery-Dependent Indices of Abundance for Gulf of Mexico Gray Triggerfish (*Balistes Capriscus)*	Nowlis, Joshua Sladek
SEDAR9-AW8	An Aggregated Production Model for the Gulf of Mexico Gray Triggerfish (*Balistes Capriscus)* Stock	Nowlis, Joshua Sladek and Steven Saul
SEDAR9-AW9	Age-Based Analyses of the Gulf of Mexico Gray Triggerfish (Balistes capriscus) Stock	Nowlis, J. S.
SEDAR9-AW10	Gulf of Mexico greater amberjack virtual population analysis assessment	Brown, C. A.,C. E. Porch, and G. P. Scott
SEDAR9-AW11	Rebuilding Projections for the Gulf of Mexico Gray Triggerfish (Balistes capriscus) Stock.	Nowlis, J. S.

2. Data Issues

The AW did not identify any deviations from the recommendations of the Data Workshop with regards to data issues.

The DW recommended that gray triggerfish in the Gulf of Mexico be considered a single stock based on its prolonged, indeterminate larval stage. For the most part, the AW agrees with this conclusion. However, the AW notes that examination of the Gulf as Eastern and Western sub-regions could help elucidate variations in stock dynamics, including variations in age at recruitment and in fishing mortality rates. Therefore, the AW suggested that age-based models be considered that used sub-regions, as well as models based on gulf-wide stocks. This is not seen as a deviation from the recommendations of the DW, as many of the indices developed for the AW from recommendations of the DW were divided into eastern and western GOM at the Mississippi River. These analyses are viewed as sensitivity runs to evaluate potential for trends in different regions rather than as a recommendation to divide the species into separate stocks.

2.1. Harvest

2.1.1. Shrimp Fleet Bycatch

Three methods were examined to estimate shrimp fleet bycatch of gray triggerfish. The initial approach was the Bayesian approach used for the red snapper assessment (SEDAR9-DW-26), but results did not appear to be as reliable for the current species, in part due to lower abundance, but also due to reasons unique to gray triggerfish. Gray triggerfish have a distribution appropriate for analysis, and are probably abundant enough for a reasonable analysis, but the species was not on the list of 22 species to be worked up during “Evaluation Protocol” observer trips aboard the shrimp fleet. Hence, shrimp observer data relevant to gray triggerfish are very, very sparse. As a result, it was not possible to obtain an estimate for bycatch with BRDs for triggerfish with the Bayesian model.

Because of doubts about the reliability of the annual estimates for any of the SEDAR 9 species from the SEDAR7 model, Nichols (SEDAR9-AW-03) also examined a delta distribution-based version of the Bayesian approach, and brought back Model 3 from the red snapper assessment (Nichols 2004, SEDAR7-DW-03). There is some evidence that the delta implementation may be underestimating bycatch, and the frequencies of occurrence of vermilion and greater amberjack are so low that one has to be suspicious about results of the CPUE portion of the delta distribution analysis. Model 3 central tendency was generally intermediate between the SEDAR7 and delta results, but the uncertainty estimates were enormous. It was not possible to partition the bycatch estimates by age as per Nichols (2004, SEDAR7-AW-20), as only a handful of fish for the SEDAR9 species have been measured across all the observer studies.

Estimates of catch from the shrimp fleet were given CVs that were double those of other harvest estimates. It was the recommendation of the AW that this was a good starting value, and if the model seemed to be fitting the shrimp bycatch at the expense of fit on the directed fishery, the CVs would be expanded to allow a better fit to the directed harvest. Based on the ability of the delta log-normal model to capture information on annual harvest, the AW accepted that model as the most appropriate method to estimate shrimp fleet harvest.

2.1.2. ***Directed Harvest***

Directed harvest estimates were aggregated into three fleets: recreational headboat, other recreational, and all commercial. Discards were ignored because of the extraordinarily high discard survival rate of gray triggerfish (SEDAR9-DW Report). At present, bycatch of juvenile fish by the shrimp fleet was not included in the surplus production model due to data limitations. The models were conditioned on catches, meaning that they were assumed to be correct measures of fishing removals. Values are shown in Table 1 and Fig. 1.

2.2. Indices

Six indices were available. The three catch fleets were used to develop three related fishery-dependent indices calculated from (1) the NMFS Southeast zone headboat survey, (2) the marine recreational fisheries statistics survey (MRFSS), and (3) commercial handline logbook entries (Sladek Nowlis 2005 - SEDAR9-AW-7). Additionally, three fishery-independent surveys were considered: (4) the Neuston larval survey (using the standardized index with diurnal cycle accounted for), (5) an age-1-based trawl survey index, and (6) a video survey. Values are shown in Table 2 and Fig. 2a and 2b (from SEDAR9-AW08, assessment). There were E, W, and Gulf-Wide indices developed from each of these datasets. For the surplus production model, only GW indices were used. For the age-structured, E and W versions were used for the fishery-dependent indices to address differences in F and selectivity.

Two general analyses of the trawl survey data were available for consideration. Nichols (SEDAR9-AW-01) developed two methods of estimating the fishery-independent trawl survey abundance. Both created a Summer Index from the Summer SEAMAP, Early SEAMAP, and Texas Closure datasets, and a Fall Index from the Fall SEAMAP, "First Fall" and Fall Groundfish data. He used a Bayesian, Markov Chain Monte Carlo approach to handle problems with missing observations, to adjust for differences among cruise programs, and to deal with observations of zero catch. Both models assumed a negative binomial distribution for samples within each dataset. The models differed in the information used to predict catch rates, and in the assumptions about the structure of survey error above the level of within-stratum variation (Nichols 2004, SEDAR7–DW-02). The output from the model provided a lognormal distribution of indexed abundance estimates from each index.

For future assessments, the group concluded that more careful examination should be given to a separate, alternative estimate of the fishery-independent trawl survey (SEDAR9-DW-23). In this alternative approach, Ingram generated indices based on an age-1 standardized index of annual average CPUE (number of fish per trawl-hour) for gray triggerfish, developed through use of a delta-lognormal model as described by Lo et al. (1992) and comparable with the standard methods used when generating fishery-dependent indices. This technique seems promising and future assessments would benefit from comparing it to the Bayesian model described above.

3. Models

Two different model types were used to examine the gray triggerfish stock condition: an aggregated stock production model and an age-based stock production. These models were selected because there was relatively little information on the age structure of the harvest of gray triggerfish. VPA models typically assume that the harvest at age is known. That is a weak assumption in the case of this fish, since length is not a very good predictor of age, and there are very few age (or length) samples taken.

The previous stock assessment used A Stock Production Model Incorporating Covariates (ASPIC) procedure (NOAA Fisheries Toolbox Version 5.10, 2005, http://nft.nefsc.noaa.gov). That model was used for the continuity case, and some exploration of that methodology was evaluated to include additional information in that model.

3.1. ASPIC MODEL

3.1.1. ASPIC Methods

The ASPIC model was explored using a number of data sets for the Gulf of Mexico gray triggerfish (*Balistes capriscus*) stock (see SEDAR9-AW-08 for more detail).

ASPIC is a non-equilibrium implementation of the Schaefer (1954, 1957) surplus production model. ASPIC also allows one to run models with other stock-recruitment relationships along the continuum identified by Pella and Tomlinson (1969). More details can be found in Prager (1994). ASPIC models presented here were conditioned on catch, forcing the model to match the catch inputs while estimating the abundance-related parameters (i.e., effort, CPUE), and all runs used the logistic or Schaefer version of the stock-recruitment relationship.

3.1.1.1. Data Sources

ASPIC relies on catch and abundance estimates to reconstruct a stock's history. Because ASPIC assumes that a unit of biomass is equivalent regardless of the age of the fish in question, life history information does not influence this aggregated production model. Instead, the model is driven entirely by catch in biomass terms and abundance indices.

3.1.1.2. Model Configuration and Equations

A "continuity case" model was constructed, in the sense that all fishery-dependent indices were used, similar to the previous assessment (Valle et al., 2001). The previous assessment removed the earlier data (1986-1989) to achieve greater stability. Our continuity case did so as well. Since understanding of this model required exploring the full time series, additional analyses were performed.

An initial model was configured using a logistic stock-recruitment relationship, equal weighting of fishery-dependent and fishery-independent indices, and starting points for parameter estimation specified as follows: initial biomass ratio (B0/K) = 0.75, maximum sustainable yield (MSY) = 1.5 m (range 1m to 4, 6, or 12m), and carrying capacity (K) equal to 10 times MSY (implies an intrinsic population growth rate parameter, r, value of 0.4). Note that total catches average about 1.5 m pounds over the time period being modeled. The consequences of varying the maximum possible MSY values were explored.

Next, a similar model was constructed except that the Neuston larval and trawl survey indices were down weighted to 1% of the influence of other indices, effectively turning them off. The base model used a logistic stock-recruitment relationship and starting points for parameter estimation specified as follows: B0/K = 0.75, MSY = 1.5 m (range 1m to 6m), and K = 10xMSY. Consequences of varying the starting point for the estimation procedure were explored. In a well-conditioned model, the final estimation result should be insensitive to the starting point of its estimation. A finding of sensitivity would raise concern about the ability to make robust conclusions from the model results.

3.1.1.3. Parameters Estimated

ASPIC estimates surplus production parameters (carrying capacity, intrinsic population growth rate) and biomass trajectories over the course of the time period modeled. These parameters are then combined to determine other useful benchmarks, such as MSY-related biomass and fishing mortality rates, and fishing mortality rate trajectories.

ASPIC contains no information on the size of the individuals or the age of the harvest, therefore has no basis to determine such characteristics of the stock as F at age, age at recruitment to the fishery, numbers of individuals in the population, or other age-dependent and size-dependent parameters.

3.1.1.4. Uncertainty and Measures of Precision

Uncertainties in the ASPIC models were explored in two main steps. First, we checked for sensitivities to the starting point of the fitting procedure by varying the initial estimates. Had that exercise indicated a well-conditioned model, then we would have examined sensitivity to one or more key parameters.

3.1.2. ASPIC Results

The first problem encountered with the gray triggerfish ASPIC model was conflicting trends among indices. The Neuston larval and trawl survey indices were negatively correlated with several others. Nonetheless, the models did converge, although the model's behavior suggested that convergence on a clear best fit was problematic given the data.

When all indices were weighted equally, results were highly dependent on the value set for the maximum boundary for the estimation of MSY. When varied from 4 to 12m, the current status of fishing on the population changed by nearly a factor of two (Fig. 3). Oddly, the best fit, in terms of sum of square errors, was the estimate produced with the smallest range (4m → SSE =36.8, 6m → SSE = 46.4, 12m → SSE = 68.4). Due to this problem and the negative correlation among the larval, trawl, and other indices, further runs were conducted with the larval and trawl indices substantially down weighted (1% of others).

Runs with these new weightings indicated a generally good fit of the model to the data (Fig. 4). Additionally, population trajectories were consistent with the general findings of indices and conceptually plausible (Fig. 5). Even with the larval and trawl indices down weighted, the model showed sensitivities to the starting points for the estimation procedure. Starting biomass values varied by more than a factor of four, although the lowest estimate was for a solution that fit poorly (Table 3). Final biomass and fishing mortality ratios also varied over a fairly broad range (Table 3, Fig. 6). And, with the exception of the run with initial estimation point for carrying capacity (K) set lower relative to MSY, all runs produced generally good fits to the data (Table 3).

As was true in the previous gray triggerfish assessment (Valle et al., 2001), limiting the analysis to only fishery-dependent indices and the timeframe to only 1990-present (2004 in our case) made the model more stable (Table 4, Fig. 7). This stability is especially notable in the contrast between Figs. 6 and 7. Both show the sensitivity of the model's predictions to where the estimation procedure started. It is apparent that the continuity case showed far less sensitivity. It also produced similar conclusions about stock status. In both the former assessment model and the continuity case, biomass declined from 1990-1999. The continuity case showed a slight increase in biomass in the first few years of the new millennium, but followed by a recent decline back to 1999 levels. Both also showed a peak in fishing mortality rates relative to MSY levels in 1995, followed by a consistent decline through the late 1990s. The continuity case shows increasing fishing mortalities from 2000 to present. These results confirm that the addition of recent data did not appreciably change the dynamics or the details of the model's predictions.

Due to the sensitivity of the model to the starting point for the estimation procedure, we have concerns about our ability to make robust conclusions from the model results. Clearly, the data are not adequate to resolve the status of the Gulf of Mexico gray triggerfish stock with any precision using an aggregated production model.

In total, the ASPIC runs were thus of limited value because of the need to use only a subset of the data. However, one finding does appear to be robust. Nearly every run conducted, both those presented here and numerous runs with draft data, indicated that the Gulf of Mexico gray triggerfish stock was overfished and experiencing overfishing. However, large differences among runs make it difficult to ascertain the magnitude of the problem.

For future research, we recommend that the performance of the ASPIC model be explored further. The sensitivities identified here are not unique to this stock (e.g., see Caribbean yellowtail snapper, SEDAR8-AW Report). Phenomena such as the apparent observation of poor status for the Gulf of Mexico gray triggerfish stock could possibly be resolved by investigating a surface of goodness-of-fit values across a broad range of parameter values. Results here and from previous experience would suggest that there is often a ridge of relatively good fit, with many small local peaks. If this is indeed the case, one might be able to draw conclusions about the status of the stock based on where the ridge lies, and might even be able to explore probabilistic projections by bootstrapping across this ridge.

3.2. State-Space Age Structured Production Model

3.2.1. State Space Age-Structured Production Model Overview

A state space age-structured production model (SSASPM) was developed for the Gulf of Mexico gray triggerfish stock. This model was possible due to great improvements in our understanding of gray triggerfish growth and age distribution, largely as a result of work by Ingram (2001).

Using our more detailed understanding of gray triggerfish growth patterns, size distributions were used to estimate age distributions. These were combined with other life history, fishery-dependent, and fishery-independent data to produce the age-structured production model.

Several decisions were made about the basic structure of the SSASPM model when used to describe gray triggerfish. These decisions were primarily based on conclusions made at the SEDAR9 Data Workshop (SEDAR9-DW-Report). Structural and data choices for the base model are summarized below, and additional details can be found in SEDAR9-AW2-09.

3.2.1.1. Stock Structure

The Data Workshop concluded that although multiple Gulf stocks of gray trigger were possible, the evidence did not support a split. Nonetheless, examination of the age or size composition from the eastern and western Gulf indicated that younger fish are generally caught in the eastern Gulf (Saul and Ingram SEDAR9-AW06), presumably as a result of differential fishing pressure. Consequently, we modeled directed fleets separately as eastern and western components, with the split occurring at the Mississippi River.

3.2.1.2. Age structure

Gray triggerfish are caught as bycatch in shrimp trawls during their first year of life. However, modeling age-0 fish presents a number of difficulties, including the technical problem that SSASPM is not yet designed to accommodate age-0 fish. Moreover, it is very likely that age-0 fish experience much heavier natural mortality than older fish and this mortality may have density-dependent relationships which could differ from the patterns of density-dependence during reproduction. We can get around some of these problems by using a model that starts with age-1 fish, but this approach also raises the issue of how to account for fishing mortality on the youngest fish (in this case, from the shrimp fleet). This issue is addressed below. Gray triggerfish can live to at least 16 years of age. However, they become uncommon after age 10. Consequently, we modeled the stock in age classes starting at 1 and ending at 10+ years old.

3.2.1.3. Stock-recruitment

SSASPM allows one to model recruitment as a Beverton-Holt or Ricker curve. We chose a Beverton-Holt curve as it is believed to fit most stocks better, excepting those that experience especially strong, population-wide density-dependent competition. For initial exploration of the model, a prior distribution of the α parameter was used. It relied on a meta-analysis by Myers and colleagues (1999), which was modified to address various life history strategies by Rose and co-authors (2001). Gray triggerfish fit Rose and colleagues' definition of a periodic life history species. The distribution of α parameters for periodic species had a median value of 12.85, a mean of 17.98, and a log-normally distributed standard deviation of 0.97. These values closely correspond with the data workshop's advice to examine a range of steepness values centered around 0.8 (α = 16) (SEDAR9-DW-Report).

3.2.1.4. Time Period

The quantity and quality of data streams for gray triggerfish improved dramatically in 1981 and again in 1986. From 1963 to 1980, only commercial catches were recorded. Starting in 1981, catch and catch-at-size information were recorded from the recreational fishery. In 1986, recreational sampling improved markedly, and by 1993 all current data streams were online. Although 1993 was the first year when virtually all sources were operational, the information in 1981 was deemed adequate to inform the model directly. The historic phase of the model stretches from 1963, when commercial catches were first reported, to 1980. Given the low level of catches in 1963, it may be reasonable to consider the stock virgin at that time. However, shrimp bycatch may have reduced it even at that early date.

3.2.2. SSASPM Methods

3.2.2.1. Data Sources

Catches

Catch information was derived from several fleets (SEDAR9-DW-Report). Based on age-structure of the catches, these were pooled into four directed fleet categories: recreational east, recreational west, commercial east, and commercial west, with the east-west split occurring at the Mississippi River. Shrimp bycatch was derived for the Gulf as a whole (Table 5, Fig. 8). Bycatch from other fleets was ignored because of the extremely low release mortality of gray triggers (SEDAR9-DW-Report).

All directed catches were converted into weights even though SSASPM is capable of taking catches in numbers. Recreational catches were reported in numbers and converted using size distributions. This conversion provided consistency with the non-age-structured surplus production model but could be explored further. Commercial catches were reported in weight and so required no conversions. Shrimp bycatch were reported in numbers.

Shrimp trawls catch both 0- and 1-year old fish, which can be difficult to distinguish without direct aging. However, we chose a model structure that started with 1-year olds for reasons described above. Using unconverted numbers would imply many more 1-year old fish were killed than was the case, while ignoring age-0 fish entirely would under represent bycatch by the shrimp fishery. Instead, a catch series was produced for age-1 equivalents. To do so, the total shrimp bycatch estimates were separated into age-0 and age-1 portions using an estimated total mortality for this age class of Z = 2. Specifically, the number of age-1 fish for a given year was calculated from the number of age-0 fish estimated to have been caught in the previous year, as reduced by estimated total mortality. Finally, when calculating the age-1 equivalency of bycatch for any year, the number of age-1 fish was added to the number of age-0 fish that would have survived from the previous year.

The resulting catch series are shown in Table 5 and Fig. 8.

Indices of Abundance

Eight indices of abundance were used for the SSASPM model. Five fishery-dependent indices were based on MRFSS data from the eastern Gulf (western Gulf data were inadequate), headboat data from the eastern and western Gulf, and commercial logbook reports for handline gear from the eastern and western Gulf. These indices are discussed in greater detail elsewhere (Sladek Nowlis, SEDAR9-AW07) and are presented in Table 6 and Fig. 9a.

Three fishery-independent indices were also used, all Gulf-wide since selectivity differences should not be a concern for scientific surveys. These included Neuston net surveys, which sample pelagic larvae, assumed to represent spawning biomass; bottom trawl surveys, which sample young fish; and video surveys, which sample adults on hard bottom habitat using a baited video camera.

These indices are presented in Table 6 and Fig. 9b.

Age Composition

Catch at age data were derived from size distributions and probabilistic assignment of age. Size distributions came from the Trip Interview Program. Interviews included the direct measurement of catches from both commercial and recreational fishers in the eastern and western Gulf (split as close to the Mississippi River as the data allowed). The resulting size distributions were converted to ages using age-length relationships developed in the SEDAR9 Data Workshop (SEDAR9-DW- Report).

Instead of directly assigning an age to each fish based on its size, a probabilistic approach was used (Saul and Ingram, SEDAR9-AW06). Fish were sorted into 25 mm length bins and a multinomial model was used to estimate the probability of a fish of a particular length class occurring in a particular age class. The probability distributions for each fish were stacked to produce an overall distribution for strata defined by year, region (eastern or western Gulf), and sector (commercial or recreational).

3.2.2.2. Base Model Configuration

Fixed Parameters

A number of life history parameters were treated as fixed and taken from the Data Workshop report (SEDAR9-DW-Report). These included:

Maturity = 87.5% of 1-year olds and 100% of other age classes assumed to be mature.

Fecundity = $170289e^{0.3159x}$, where x = age.

M = 0.27 for all modeled age classes.

$FL = 423.4\ (1-e^{-0.4269(x+0.6292)})$, where FL = fork length in mm and x = age.

$Wt = 4.4858 * 10^{-8}\ FL^{3.0203}$, where Wt = weight in lbs and FL = fork length in mm.

Parameters Estimated

Several parameters were estimated, or at least explored over a range of values. These included:

The unfished recruitment levels;

Catchability for each fleet and index; and

Fleet selectivities.

In tuning the Gulf of Mexico gray triggerfish SSASPM model, three elements proved to have strong influence on the results. The first element was the α parameter from the stock-recruitment relationship. The second was a variance scalar applied to recruitment deviations. The third was a similar variance scalar applied to the shrimp fleet fishing effort.

α

When run using the prior distribution of α values from the meta-analysis of periodic life history strategists, the SSASPM model estimated a very high parameter value (70.9, corresponding to a steepness of 0.95). Alternatively, several runs were conducted using highly constrained estimates of α, ranging from 6 to 36 (runs with fixed values had the disconcerting property that they usually produced non-positive-definite Hessian matrices, suggesting instability). A reasonable base model might be the one that used a constrained $\alpha = 12$, which estimated $\alpha = 13.5$, just above the median of the meta-analytic distribution. The equivalent steepness = 0.77.

Recruitment Deviations

Initially, the model was constructed with a variance scalar applied to recruitment deviations that was high but on par with those applied to index observation errors (i.e., 2). Configured like this, the model predicted recruitment from the mid-1980s to the mid-1990s at levels that exceeded the underlying maximum recruitment parameter (Fig. 10a). This disconnect could have been addressed by assuming it was a signal that recent recruitment has been higher than it was in the past or by assuming that the deviations were inadequately constrained. Using the second approach, the variance scalar was set to 0.05, below even the value applied to effort deviations for most fleets (0.223). When constructed this way, the model predicted recruitment patterns (Fig. 10b) much more in line with dynamics of the population as indicated by abundance indices.

Shrimp Effort Deviations

Initially, the model was constructed with variance scalars applied to effort deviations of all fleets at values that corresponded with CVs of 50% (0.223). For most fleets, we don't have independent measures of effort and there is real potential for big fluctuations, especially given the less preferred nature of gray triggerfish. However, we do have independent estimates of shrimp fleet effort dynamics, derived for the recent Gulf of Mexico red snapper assessment (Nance 2004, SEDAR7-DW-24). The effort series for eastern and western Gulf fleets are shown in Fig. 11a. When the variance scalar for shrimp effort was set at the same level as other fleets, the model estimated large fluctuations in shrimp effort, which did not agree well with the independent estimates (Fig. 11b). When this variance scalar was set lower (0.0392, equivalent to a 20% CV), the modeled effort fluctuations were more on par with those estimated in the red snapper assessment (Fig. 11b).

Uncertainty and Measures of Precision

A number of sensitivity analyses were performed. These runs explored the degree to which the conclusions from the base model were sensitive to potential inaccuracies in the specification of various model parameters. The sensitivity runs included:

Runs described above, which explored a range of α, recruitment deviations, and shrimp effort deviations values.

Beginning the burning-in period in 1950 instead of 1963.

Using natural mortality values of M = 0.25 or M = 0.3.

3.2.3. SSASPM Results

3.2.3.1. SSASPM Overall Model Fit

The base model generally performed well compared to sensitivity runs, according to AIC scores (Tables 7 and 8). There were some exceptions, though. Fits were best with very high α values, and so runs with values constrained higher than the base or estimated were more parsimonious with the data than the base run. Additionally, the model fit the data slightly better when natural mortality were set at M = 0.3.

3.2.3.2. SSASPM Catch Fits

Catches fits were mediocre for the base model (Fig. 12), although they did not improve markedly in any sensitivity analyses. Directed commercial catches showed the best fit, while shrimp bycatch was too flat (see discussion, above, of effort deviations) and recreational catches only captured some of the patterns of the underlying data.

3.2.3.3. SSASPM Index Fits

Indices fit better. They generally captured the broad pattern of the underlying data but missed most spikes (Fig. 13). Since the spikes may represent data issues rather than true population fluctuations, this result may be desirable.

3.2.3.4. Stock Recruitment Parameters

As is typical for most fisheries models, especially those with relatively short time series of information, the stock-recruitment relationship was poorly resolved. In addition to the *a priori* considerations paid to this important issue, we performed some *posteriori* analyses to further explore it. To do so, we began by examining the results from the base run. Only years with extensive data were used (1986-2004), and these were examined to identify what the recent pattern of stock-recruitment has been, noting that these recent years included recruitment deviations that could have produced a different relationship than the underlying one defined by the stock-recruitment parameters themselves. The result indicated a steepness of 0.65 (Fig. 14a), a bit lower than the median value proposed in the base run (which corresponded to a steepness of 0.77. This difference was relatively minor and provided further support for the proposed base run.

However, this result was highly sensitive to the degree to which recruitment deviations were constrained. Recall from the earlier discussion that they were constrained so as to resolve the inconsistency between recent recruitment levels and the stock-recruitment relationship. When these constraints were removed, the model produced a series of recruitments with a steepness of 0.2, suggesting no density-dependent compensation at reduced abundance (Fig. 14b). Alternatively, when recruitment deviations were eliminated (i.e., fully constrained), so that recruitment in the model had to fit the internal stock-recruitment relationship, recruitment since 1986 appears to follow a relationship with a steepness of 0.976 (Fig. 14c), near the maximum of 1. The ramifications of various steepness values were explored in sensitivity analyses and do have a significant influence on estimated stock status.

3.2.4. Base Model Recommendation

Weighing all of the evidence, the assessment workshop panel recommended the originally-proposed base model to serve that purpose for the gray triggerfish assessment. The rationale for doing so was as follows. First, although recruitment deviations were discovered to play a more important role in determining stock status than was originally anticipated, this finding does not change the logic behind the constraints that were used on the size of deviations. The constrained deviations limited the model from estimating greater-than-virgin recruitment levels from the mid-1980s through the mid-1990s (Fig. 10). Note, though, that another approach would have been to assume that recent recruitment has been higher than the underlying stock-recruitment relationship would suggest.

The other issue to resolve is an appropriate treatment of the α parameter in the stock-recruitment relationship. Although the best fits were associated with high values of α, the improvement in fit over a wide range of α values was slight (Table 7). Thus, we can conclude that the data were not very informative about the stock-recruitment relationship. Our additional efforts to examine this relationship by looking only at the most data rich years (1986-2004) were also inconclusive (Fig. 14). Accepting the treatment of recruitment deviations recommended above, the value of α is driven lower by examining only the most data rich years (Fig. 14a).

Thus, we have the data en masse providing weak justification for using a high steepness and the most informative data providing a weak justification for lower steepness. Lacking any conclusive analysis illustrating that the data point to a single value for this parameter, the assessment workshop panel concluded that using the median value of the meta-analysis was appropriate. To aid consideration of this meta-analysis, the species used are listed in Table 9.

3.2.5. Stock Status

Although the base model's behavior was not ideal, it may have been adequate. Greater confidence was gained by examining the key management benchmarks across a wide range of sensitivity analyses (Tables 7 and 8). Current status as a function of SPR- and MSY-based management benchmarks was consistent with those analyses across a range of input parameters.

Using SPR benchmarks, the base run and most sensitivity analyses indicated that the Gulf of Mexico gray triggerfish stock was overfished and experiencing overfishing (Tables 7 and 8, Fig. 15). Exceptions included the $\alpha \sim 6$, M = 0.3, no or large recruitment deviations, and equal shrimp effort deviations runs, which estimated the stock was not overfished (but in most cases was close to it). All runs indicated overfishing was occurring relative to a 30% SPR benchmark.

Using MSY benchmarks, the base run and most sensitivity analyses also indicated that the Gulf of Mexico gray triggerfish stock was overfished and experiencing overfishing (Tables 7 and 8, Fig. 16). The only exceptions here were the two highest α runs, which indicated the stock was above SSB_{MSY} and not experiencing overfishing; the M = 0.3 run, which indicated the stock was nearly but not quite overfished but still experiencing overfishing; the large recruitment deviations run which indicated the stock was just above SSB_{MSY} levels but still experiencing overfishing.

According to the base run, the stock dropped below MSY levels in the late 1970s, recovered briefly in the late 1980s and has steadily declined since 1990 (Fig. 17a). The model indicates that stock abundance reflects overfishing, which began in the 1970s and has continued to the present day (Fig. 17b).

4. Assessment Workshop Panel Recommendations and Comment

4.1. Model Comparisons

4.1.1. Compare and Contrast Models Considered

4.1.1.1. Aggregated Production Model (ASPIC implementation)

The ASPIC model was the only model considered in the previous assessment of gray triggerfish (Valle et al., 2001). The current application of the model does add the benefit of allowing uncertainty in model inputs. As in the prior assessment, the ASPIC model was very sensitive to input parameters. After updating the continuity case, additional runs of the model deleted some of the fishery-independent indices and provided more consistent results. However, since there is probably some correlation between fishery-dependent indices and harvest, the AW is concerned that removal of information from the model might provide a better fit to the data but may not increase the ability of the model to characterize the status of the stock. As was also noted in the vermilion snapper portion of this report, the model does not have information on age (or size) selectivity compared to age at maturity, thus may not capture resiliency of the stock.

4.1.1.2. State-Space Age-Structured Production Model (SSASPM)

The AW preferred the SSASPM model for several reasons. It incorporates information on life history and on the age structure of the harvest. This allows information on relative ages of maturity and harvest to be evaluated within the model structure. In a case such as gray triggerfish, where selectivity seems to be different across the geographic range, this information has the potential to provide more realistic evaluation of the stock status. While the model seemed to still have significant problems coming to resolution regarding the exact status of the stock, the general consensus of the outputs was persuasive regarding the estimated condition of the stock.

4.2. Preferred Model Recommendation

The AW preferred the SSASPM on the basis that it considers more of the biology and fishery characteristics of gray triggerfish. At the time of the first AW, participants had not seen the results of the SSASPM model, but were concerned about the shortcomings of the ASPIC model discussed above, and felt that this model could be more informative. Based on the presentation and evaluation of the model and results at the second AW, the participants present considered this model preferable, and recommended using it as the basis of determining stock status. The consistency of the ASPIC and the SSASPM models in their stock determination criteria added a degree of confidence in the models' ability to represent the condition of the stock.

4.3. Selected Rebuilding Trajectories

Given the likely determination that Gulf of Mexico gray triggerfish are overfished and experiencing overfishing, rebuilding scenarios were explored to facilitate management action. Outputs were taken directly from the base SSASPM model and these were used to project the population forward in time under various scenarios. Given the relative ease with which the stock rebuilt to the legally-required MSY abundance levels, analyses were limited to simple projections that linked all fleets together. In other words, overall fishing mortality rates were manipulated but the selectivity-at-age patterns remained constant, which is the equivalent of assuming that all catch cuts were distributed proportionally across all directed and bycatch fleets. Moreover, it was assumed that the status determination will become official in early 2006 and that management action would take place in early 2007.

Detailed tools for achieving rebuilding were not explored. Yet management choices will be simplified by the fact that gray triggerfish survive catch and release remarkably well, at least in directed fleets. As a result, size or trip limits can be used effectively for all but the shrimp fleet.

According to the proposed base assessment model, the gray triggerfish stock was at about 60% of MSY abundance levels and experiencing about 145% of MSY fishing mortality rates in 2004 (Fig. 17). Scenarios explored the rebuilding of this stock back to MSY abundance levels and used a maximum timeframe of 10 years.

Under a no fishing scenario, in which all directed and bycatch fisheries were eliminated, gray triggerfish were able to rebuild extremely quickly—less than 2 years after fishing were eliminated (Table 10; Fig. 18).

Without any management action, the stock does not fare so well. It is currently experiencing overfishing and, as a result, it fails to recover at all under current fishing mortality rates (Table 10; Fig. 19).

If fishing mortality rates were reduced by about 30%, to F_{MSY} levels, the stock would also fail to rebuild fully to MSY abundance levels but overfishing would be halted if using MSY as a benchmark (Table 10; Fig. 20). If using 30%SPR, as is currently stated in the management plan, overfishing would still occur even with this reduction.

If fishing mortality rates were reduced by about 40%, to $F_{30\%SPR}$ levels, overfishing would end regardless of the benchmark used. And the stock would rebuild to nearly MSY levels by the end of 2016 (Table 10; Fig. 21). It would take only an extremely minor additional reduction of 2% to achieve rebuilding within this timeframe (Table 9; Fig. 22).

Finally, a scenario was explored using a common definition of optimum yield, noting that the current management plan has not identified this benchmark. Using 75% of the fishing mortality rate associated with MSY (i.e., $F_{OY} = 0.75F_{MSY}$) achieved rebuilding by 2012 but required cutting the fishing mortality rate nearly in half. The benefits of this strategy would primarily be in the future, noting that by

2016 catches under this lighter fishing pressure would nearly equal those under other, more aggressive fishing pressure scenarios (Table 10; Fig. 23).

5. References

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6. Tables

TABLE 1—Catches by Fleet (in lbs)

Year	Headboat	Other recreational	Commercial	Total
1986	93,772	864,229	95,629	1,053,630
1987	76,584	1,115,841	123,603	1,316,027
1988	134,501	1,592,524	195,062	1,922,088
1989	162,639	1,672,689	317,632	2,152,960
1990	263,606	2,184,440	459,038	2,907,083
1991	187,270	1,758,437	444,530	2,390,237
1992	222,532	1,497,032	450,195	2,169,759
1993	215,132	1,268,698	558,728	2,042,558
1994	222,428	1,077,372	404,720	1,704,519
1995	200,838	1,125,930	337,877	1,664,645
1996	156,388	673,879	267,516	1,097,783
1997	129,477	605,403	184,689	919,569
1998	107,159	517,647	176,723	801,530
1999	82,666	388,552	219,020	690,238
2000	67,913	341,086	158,137	567,136
2001	82,164	531,165	176,182	789,511
2002	110,960	670,356	235,563	1,016,879
2003	128,529	775,486	251,810	1,155,825
2004	115,965	889,761	218,533	1,224,258

TABLE 2—Index Values (CPUE)

Year	Headboat	MRFSS	Commercial Handline	Larval	Trawl	Video
1986	0.8094	1.7697	0.8122			
1987	0.6924	0.8929	0.5985	0.8678		
1988	0.9383	2.5591	0.4037	0.4113		
1989	1.3966	3.0805	0.2314	0.3900		
1990	2.1313	5.5935	0.3990	1.1514		
1991	1.9838	3.0457	0.8050	1.3974		
1992	2.0453	3.1726	2.6547	0.8699	1.8348	
1993	1.7649	1.3323	1.5312	0.9001	0.3532	1.0011
1994	1.4882	1.2347	1.4616	1.0343	1.0221	0.9002
1995	1.2666	2.6720	1.4322	1.0305	1.3458	0.8517
1996	1.0442	1.1268	0.8714	0.6992	0.5557	0.7936
1997	1.0093	0.7435	0.8598	0.7347	0.7730	1.6737
1998	0.9698	0.5663	0.8463	0.2781		
1999	0.7009	0.6776	0.7264	0.2326	0.7434	
2000	0.5770	0.5961	0.6296	2.4034	0.3067	
2001	0.6140	0.6567	0.6727	0.3967	1.5582	0.1430
2002	0.8430	0.8021	0.9638	0.5497	1.5220	0.8019
2003	0.8353	0.7308	1.0854	0.2740		
2004	0.8867	0.8609	0.9196	0.5518		

TABLE 3—Sensitivities to Starting Points of the Estimation Procedure
Results from models where larval and trawl survey indices were down weighted. The base model used a logistic stock-recruitment relationship and starting points for parameter estimation specified as follows: B0/K = 0.75, MSY = 1.5 m (range 1m to 6m), and K = 10xMSY.

Model	Bratio	Fratio	Bo ratio	Bo (m)	SSE
Base	0.2828	1.94	0.6661	3.41	31.498
max MSY 4 m lb	0.2128	3.107	0.9872	8.46	52.799
Bo ratio 0.25	0.3003	1.901	0.7408	3.76	25.26
MSY 2.1 m lb.	0.2047	3.509	1.137	9.97	38.58
K=5*MSY	0.2336	2.146	0.7069	2.3	1348

TABLE 4—Sensitivities to Starting Points of the Estimation Procedure in Continuity Case
Results from models where only fishery-dependent indices were used and the timeframe was restricted to 1990-2004. The base model used a logistic stock-recruitment relationship and starting points for parameter estimation specified as follows: B0/K = 0.75, MSY = 1.5 m (range 500t to 6m), and K = 10xMSY.

Model	Bratio	Fratio	Bo ratio	Bo (m)	SSE
Base	0.2762	1.933	1.009	4.666	2.959
max MSY 4 m lb	0.3547	1.834	1.614	5.744	3.003
Bo ratio 0.25	0.3578	1.808	1.655	5.632	2.996
MSY 2.1 m lb.	0.3826	1.795	1.945	6.438	3.071
K=5*MSY	0.4085	1.756	2.46	7.517	3.204

TABLE 5—Gulf of Mexico Gray Triggerfish Catches
Directed catches are reported in pounds, while shrimp bycatch is reported in age-1 equivalent fish (described in text).

YEAR	Recreational EAST	Recreational WEST	Commercial EAST	Commercial WEST	Shrimp Age-1 Equivalent
1963			3100	4200	
1964			15700	4300	
1965			17400	4300	
1966			8600	5200	
1967			12200	5200	
1968			8600	3900	
1969			14600	7700	
1970			16000	8200	
1971			30500	9900	
1972			47400	15200	
1973			40000	13200	112278
1974			40000	13100	342365
1975			62000	16000	380204
1976			69700	14800	220050
1977			50096	9290	189051
1978			48518	10197	460315
1979			65670	35733	1771057
1980			65422	31001	606638
1981	748779	179617	64498	25362	1467734
1982	2032601	362711	62959	33714	1206518
1983	397614	387301	49588	23831	1462755
1984	120970	844623	37445	32749	304994
1985	280865	479950	54840	37786	855586
1986	898096	79077	72858	22771	279374
1987	1135998	199066	89313	34290	1044555
1988	1638073	158328	137978	57084	1364168
1989	1765965	212002	230361	87271	906437
1990	2313261	184941	359686	99351	1286703
1991	1688392	399955	341319	103211	523154
1992	1434485	688825	338119	112076	3100516
1993	1317044	309425	381279	177448	432660
1994	1152103	186425	251578	153141	1951471
1995	1139967	329441	207212	130664	1065855
1996	618125	226006	142185	125332	1498133
1997	664794	100211	107780	76909	1751775
1998	560509	93309	106153	70571	1004208
1999	445430	43997	116194	102826	242741
2000	337241	109209	63042	95095	1656166
2001	487622	152571	108464	67718	490376
2002	721872	77016	148600	86963	5115407
2003	856626	58622	166425	85385	854441
2004	951559	78092	141411	77122	167162

TABLE 6—Gulf of Mexico Gray Triggerfish Relative Abundance Indices.
Fishery-dependent and independent indices were transformed separately, in such a manner that each index averaged 1 over the years where all indices of that category were available (1993-2004 for FD; 1992-97 and 2001-02 for FI).

Year	MRFSS EAST	Headboat EAST	Headboat WEST	Commercial Handline EAST	Commercial Handline WEST	Neuston FI Survey	Trawl FI Survey	Video FI Survey
1981	1.6548							
1982	1.4133							
1983	0.9873							
1984	5.9438							
1985	0.2173							
1986	3.641	0.7848	0.8973			0.8122		
1987	1.1654	0.5169	0.8861			0.5985	0.5298	
1988	2.0648	0.6791	1.2201			0.4037	0.4556	
1989	3.3945	1.5569	1.1254			0.2314	0.8096	
1990	7.1257	2.4939	1.5849			0.399	0.1866	
1991	2.9727	1.9669	1.8749			0.805	3.0919	
1992	2.6319	2.2737	1.6657			2.6547	0.1815	1.8348
1993	1.6326	1.7824	1.6771	1.7512	1.0824	0.9001	1.5339	1.0009
1994	1.4808	1.3821	1.6302	1.6507	1.3808	1.0343	1.4693	0.9002
1995	2.2807	1.2025	1.4973	1.7105	1.5589	1.0305	0.616	0.8518
1996	1.3233	0.8525	1.527	0.753	0.9714	0.6992	0.5421	0.7937
1997	0.742	0.9032	1.3769	0.6298	0.7733	0.7347	0.37	1.6738
1998	0.5624	0.7762	0.9371	0.5943	1.0118		0.0351	
1999	0.5828	0.8224	0.4182	0.5719	1.3704	0.2326	0.8293	
2000	0.4573	0.5781	0.4236	0.4171	1.0247	2.4034	1.4431	
2001	0.7023	0.6481	0.5009	0.6182	0.7079	0.3967	2.6692	0.143
2002	0.7272	0.9847	0.5528	1.1006	0.7565	0.5497	0.618	0.8018
2003	0.7016	0.9971	0.6782	1.2278	0.6793		0.524	
2004	0.8071	1.0708	0.7807	0.975	0.6826		0.6266	

TABLE 7—Stock Recruitment α Runs. 292 data points, 170 estimated parameters, base run described in the text used an *α* value of 12 since the estimation procedure tended to inflate this number in the final estimate (median steepness was ~ 13).

	α ~ 6	*α* ~ 9.33	Base	*α* ~ 16	*α* ~ 36	Est *α*
FIT						
Estimated params	170	170	170	170	170	170
Objective function	383.8	373.6	369.9	367	362.8	364.6
AIC	1108	1087	1080	1074	1066	1069
BENCHMARKS						
Alpha	8	11	13.5	17.4	37.1	70.9
Steepness	0.67	0.73	0.77	0.81	0.9	0.95
Max recr (m)	3.462	3.081	2.911	2.758	2.504	2.409
SSB_{VIRGIN} (m)	12.118	10.782	10.188	9.652	8.764	8.433
SSB_{MSY} (m)	3.083	2.447	2.158	1.881	1.36	1.117
$SSB_{20\%tSPR}$ (m)	1.052	1.298	1.391	1.46	1.559	1.593
F_{MSY}	0.273	0.332	0.372	0.424	0.594	0.74
$F_{30\%SPR}$	0.331	0.327	0.325	0.324	0.321	0.32
MSY (m)	1.846	1.848	1.861	1.887	1.988	2.067
CURRENTLY						
SSB_{2004} (m)	1.208	1.287	1.326	1.362	1.426	1.45
SSB_{2004}/SSB_{MSY}	0.39	0.53	0.61	0.72	1.05	1.3
$SSB_{2004}/SSB_{20\%tSPR}$	1.15	0.99	0.95	0.93	0.91	0.91
F_{2004}	0.561	0.545	0.537	0.531	0.52	0.515
F_{2004}/F_{MSY}	2.05	1.64	1.44	1.25	0.87	0.7
$F_{2004}/F_{30\%SPR}$	1.69	1.67	1.65	1.64	1.62	1.61

TABLE 8—Sensitivity Runs. 292 data points, base run described in Table 3.

	Base	1950 start	M 0.25	M 0.3	No recr. devs	Lg recr devs	Eq effort devs
FIT							
Estimated params	170	170	170	170	146	170	170
Objective function	369.9	389.8	378.5	358.8	431.4	391.3	379.1
AIC	1080	1120	1097	1058	1155	1123	1098
BENCHMARKS							
Alpha	13.5	13.4	14	13.1	14.2	12.7	13.6
Steepness	0.77	0.77	0.78	0.77	0.78	0.76	0.77
Max recr (m)	2.911	3.061	2.867	3.03	3.366	1.798	2.969
SSB_{VIRGIN} (m)	10.188	10.713	11.784	8.481	11.782	6.293	10.393
SSB_{MSY} (m)	2.158	2.276	2.49	1.807	2.455	1.37	2.197
$SSB_{20\%tSPR}$ (m)	1.391	1.456	1.629	1.136	1.646	0.829	1.418
F_{MSY}	0.372	0.371	0.339	0.427	0.384	0.343	0.379
$F_{30\%SPR}$	0.325	0.326	0.294	0.378	0.327	0.313	0.33
MSY (m)	1.861	1.955	1.92	1.828	2.177	1.122	1.906
CURRENTLY							
SSB_{2004} (m)	1.326	1.359	1.257	1.436	1.779	1.486	1.437
SSB_{2004}/SSB_{MSY}	0.61	0.6	0.5	0.79	0.72	1.08	0.65
$SSB_{2004}/SSB_{20\%tSPR}$	0.95	0.93	0.77	1.26	1.08	1.79	1.01
F_{2004}	0.537	0.529	0.559	0.504	0.433	0.513	0.511
F_{2004}/F_{MSY}	1.44	1.43	1.65	1.18	1.13	1.5	1.35
$F_{2004}/F_{30\%SPR}$	1.65	1.62	1.9	1.33	1.32	1.64	1.55

TABLE 9—Species Used in Meta-Analysis of α Parameter Values
Adapted from Rose et al. (2001) using "periodic" species.

Species	α
Pacific hake	1.9
bombay duck	2
chub mack	2.4
silver hake	2.7
southern bluefin	2.9
medit. Horse mack	3.5
walleye pollock	5
atlantic bluefin tuna	5.2
Gulf menhaden	5.3
bigeye tuna	5.3
European flounder	5.3
alewife	5.7
northern pike	6.1
black angler	6.7
yellowfin tuna	9.3
walleye	9.5
Blue whiting	10
atka mack	12
horse mack	12.1
Pacific sardine	12.7
haddock	13
yellowtail flounder	13
hake	18
pollock	18
shad	18.5

striped bass	18.6
Atl Herring	22.1
Atl. Menhaden	24.8
plaice	25.1
Atlantic cod	26
white croaker	26.1
sole	28.7
greenland halibut	29.3
swordfish	30.1
whiting	30.8
atlantic mack	31.8
blueback herring	31.9
Gulf of Mexico red snapper	47.8
new zealand snapper	65.6
scup	74.6

TABLE 10—Catches Under Various Rebuilding Scenarios
Lighter shading represents the ending of overfishing while darker shading represents the achievement of rebuilding.

Year	No Fishing			Current F			MSY		
	Catch	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy
2004	1.34	1.44	0.6	1.34	1.44	0.6	1.34	1.44	0.6
2005	1.29	1.44	0.58	1.29	1.44	0.58	1.29	1.44	0.58
2006	1.27	1.44	0.57	1.27	1.44	0.57	1.27	1.44	0.57
2007	0	0	0.88	1.25	1.44	0.57	0.99	1	0.64
2008	0	0	1.12	1.24	1.44	0.56	1.06	1	0.69
2009	0	0	1.38	1.23	1.44	0.56	1.12	1	0.72
2010	0	0	1.67	1.22	1.44	0.55	1.17	1	0.75
2011	0	0	1.96	1.22	1.44	0.55	1.21	1	0.78
2012	0	0	2.25	1.22	1.44	0.55	1.24	1	0.8
2013	0	0	2.55	1.21	1.44	0.55	1.27	1	0.82
2014	0	0	2.84	1.21	1.44	0.55	1.29	1	0.83
2015	0	0	3.11	1.21	1.44	0.55	1.31	1	0.85
2016	0	0	3.34	1.21	1.44	0.55	1.32	1	0.85

Year	30% SPR			Min F to Rebuild			OY		
	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy	Catch (m)	F/Fmsy	B/Bmsy
2004	1.34	1.44	0.6	1.34	1.44	0.6	1.34	1.44	0.6
2005	1.29	1.44	0.58	1.29	1.44	0.58	1.29	1.44	0.58
2006	1.27	1.44	0.57	1.27	1.44	0.57	1.27	1.44	0.57
2007	0.9	0.87	0.67	0.89	0.86	0.67	0.81	0.75	0.7
2008	0.98	0.87	0.73	0.97	0.86	0.73	0.9	0.75	0.77
2009	1.06	0.87	0.78	1.05	0.86	0.79	0.98	0.75	0.84
2010	1.12	0.87	0.83	1.12	0.86	0.84	1.06	0.75	0.91
2011	1.18	0.87	0.87	1.17	0.86	0.88	1.12	0.75	0.96
2012	1.22	0.87	0.9	1.22	0.86	0.91	1.18	0.75	1.01
2013	1.26	0.87	0.93	1.25	0.86	0.94	1.22	0.75	1.05
2014	1.29	0.87	0.95	1.28	0.86	0.96	1.26	0.75	1.08
2015	1.31	0.87	0.97	1.31	0.86	0.98	1.29	0.75	1.11
2016	1.33	0.87	0.98	1.33	0.86	1	1.31	0.75	1.13

7. Figures

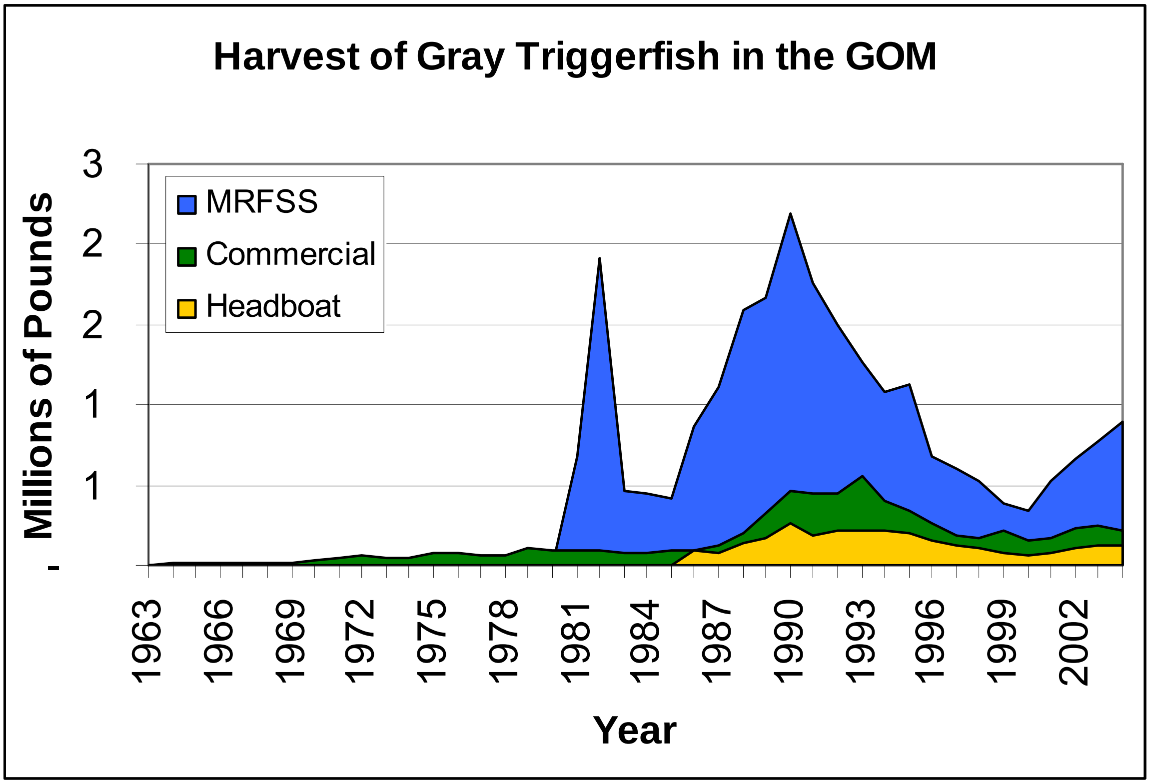


Fig. 1—Gulf of Mexico Gray Triggerfish Catches By Fleet
Values stacked to demonstrate trends in cumulative landings. Note: MRFSS survey began in 1981, and Headboat Survey (HB) began in 1984.(from SEDAR9-AW-08)

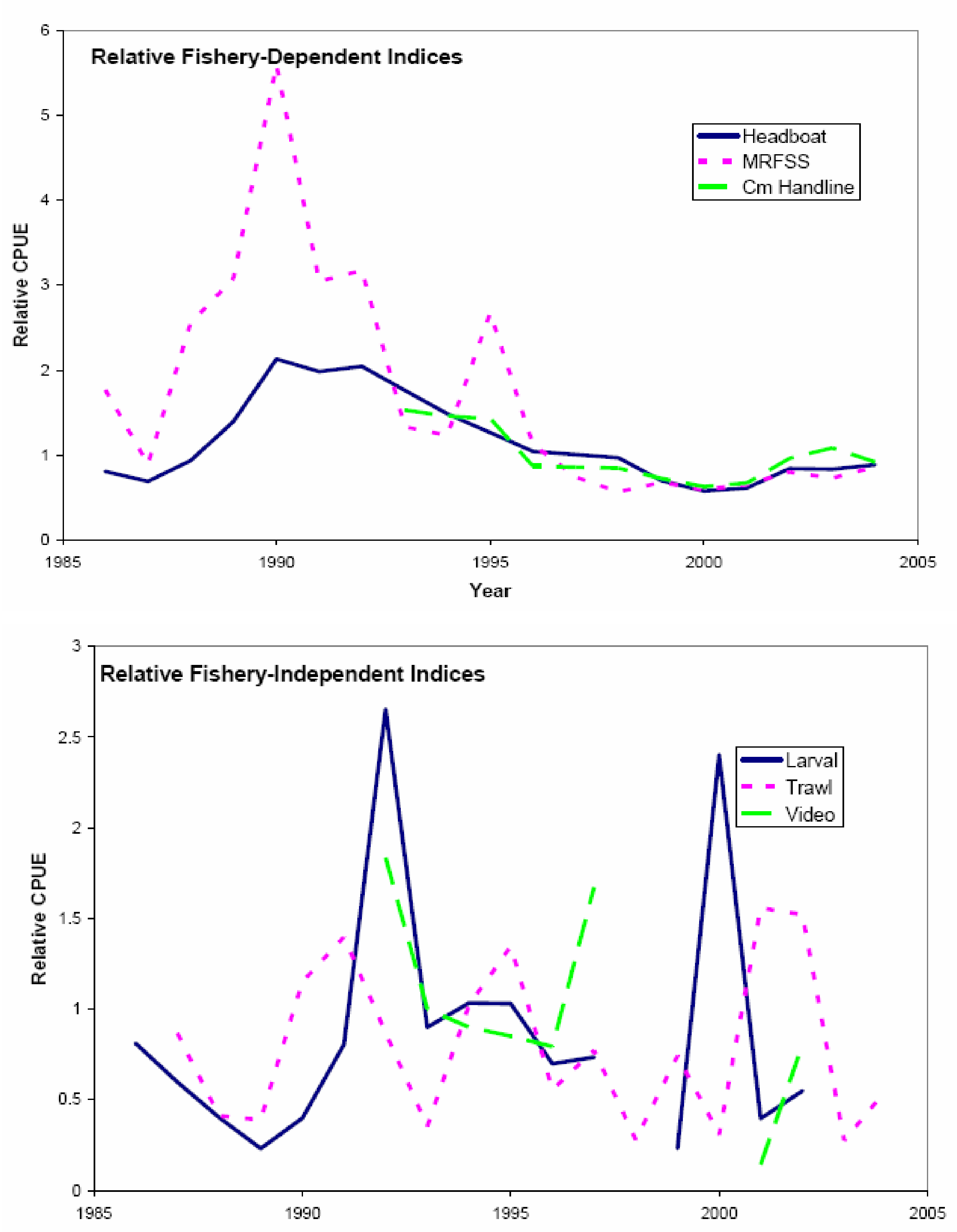


FIG. 2—Gulf of Mexico Gray Triggerfish Indices of Abundance
(a) Fishery-independent and (b) fishery-dependent indices of abundance. Normalized across the years where all indices were calculated (1992-97, 2001-02 for FI; 1993-2004 for FD).

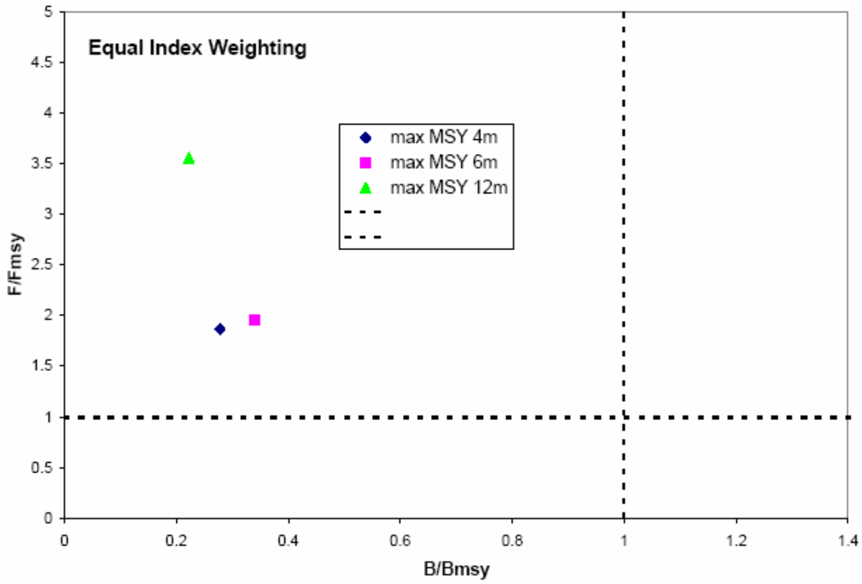


FIG. 3—Extreme Sensitivities, Equal Index Weightings
All runs had same inputs and varied only in constraints placed on MSY estimation. From SEDAR9-AW-08.

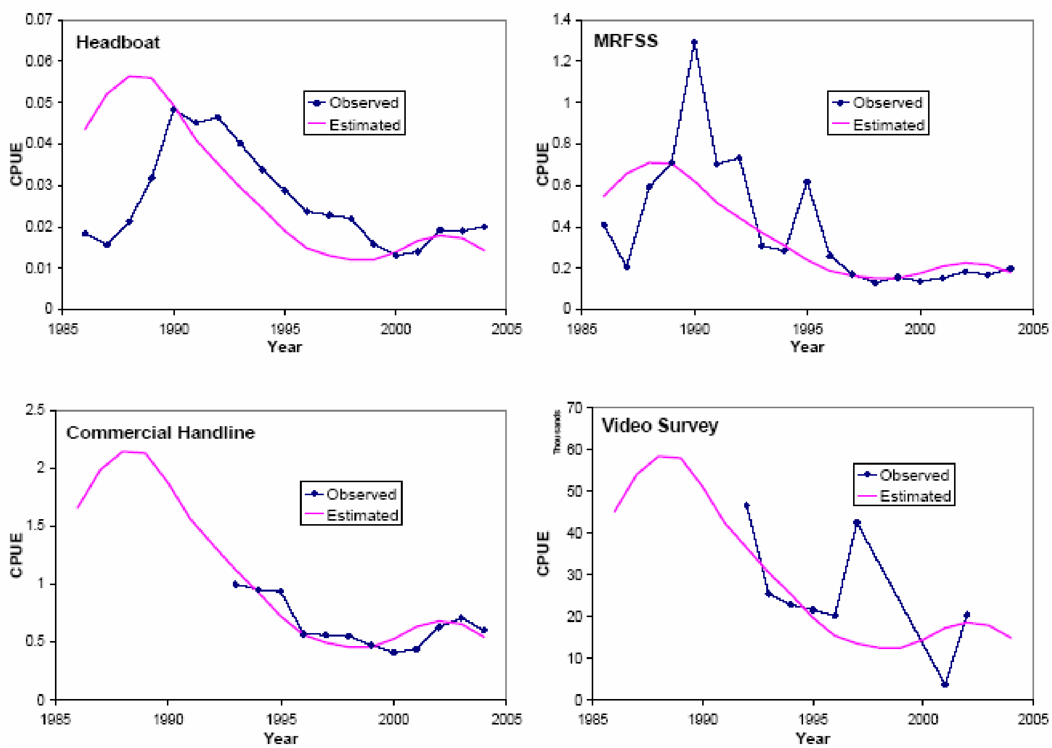


FIG. 4—Base ASPIC Model Fit to Indices
(A) Headboat, (B) MRFSS, (C) Commercial Handline, (D) SEAMAP Video Survey.

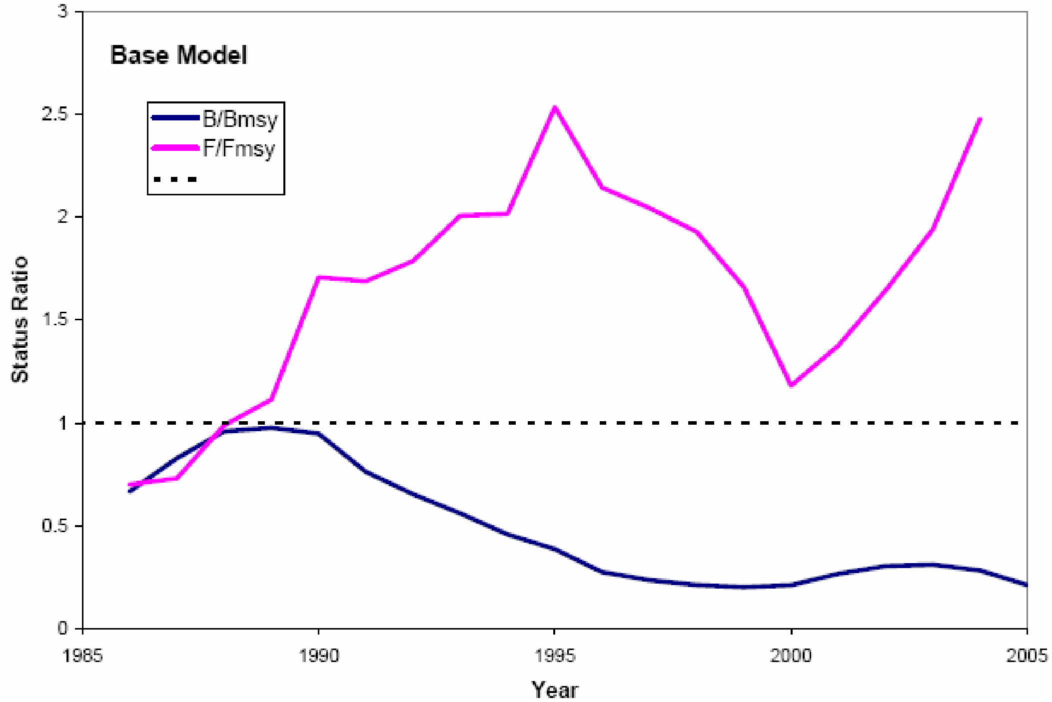


FIG. 5—Status Trajectories of ASPIC Base Model

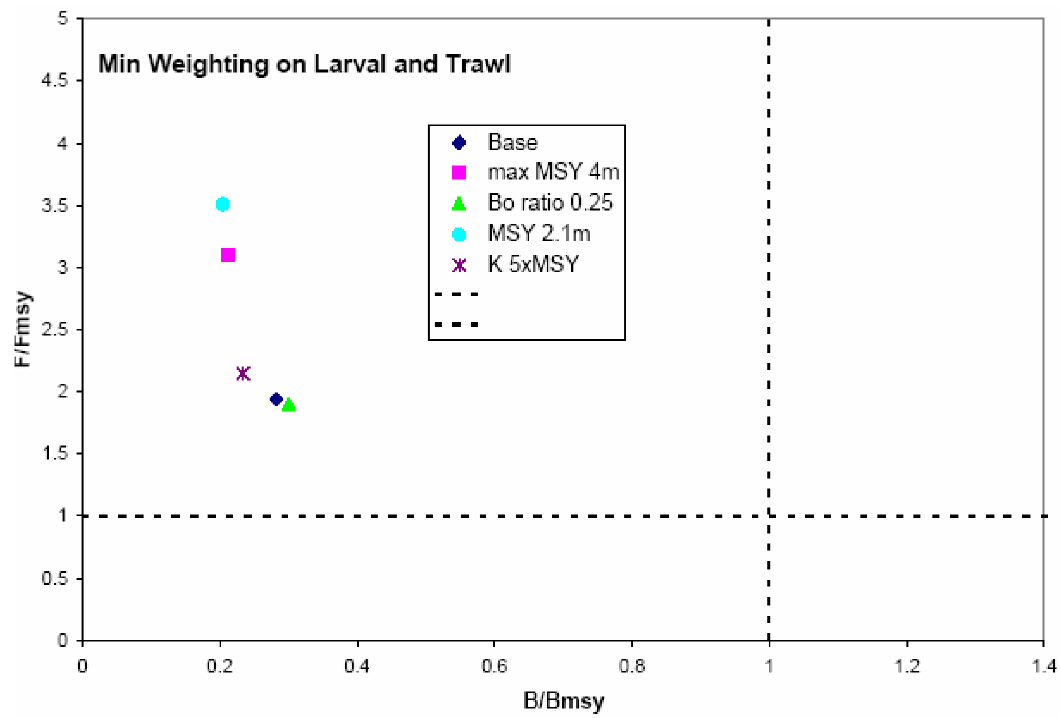


FIG. 6—Continued Extreme Sensitivities, Minimal Weightings on Larval and Trawl Indices All runs had same inputs and varied only in constraints placed on MSY or in the starting point used for the estimation procedure. From SEDAR9-AW-08.

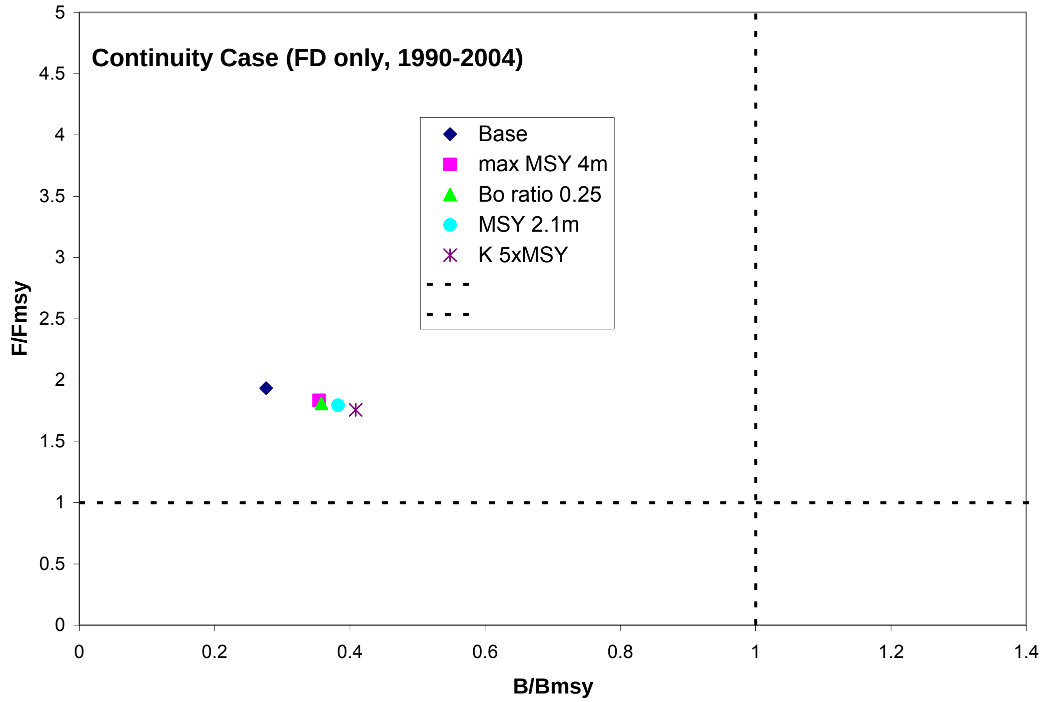


FIG. 7—Less Sensitive, Continuity Case
Similar figure as Figs. 5 and 6, but restricting analysis to fishery-dependent indices and years 1990-2004 increased stability.

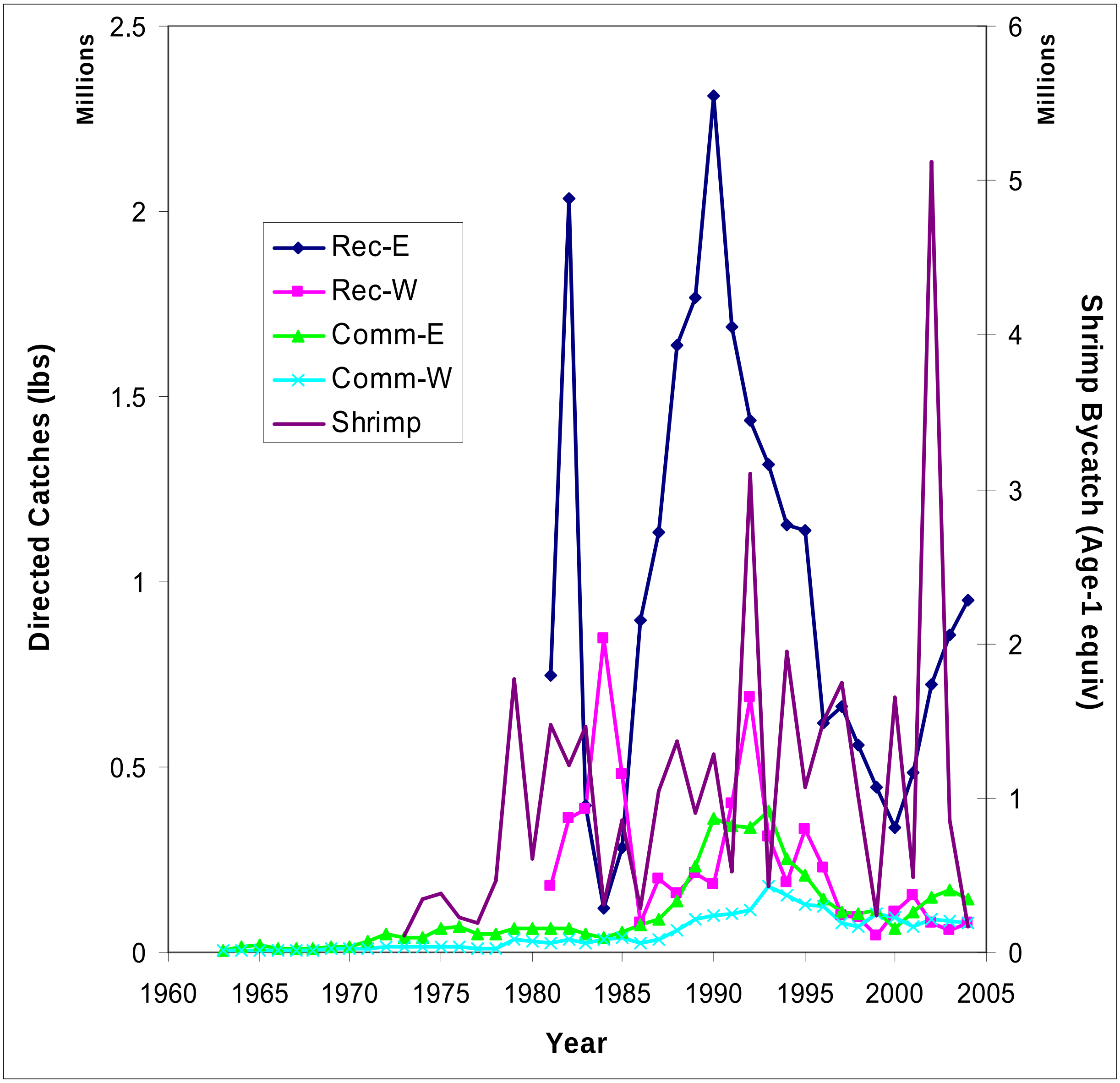


FIG. 8—Gulf of Mexico Gray Triggerfish Catches By Fleet and Region
Directed catches are reported in pounds, while shrimp bycatch is reported in age-1 equivalent fish (described in text).

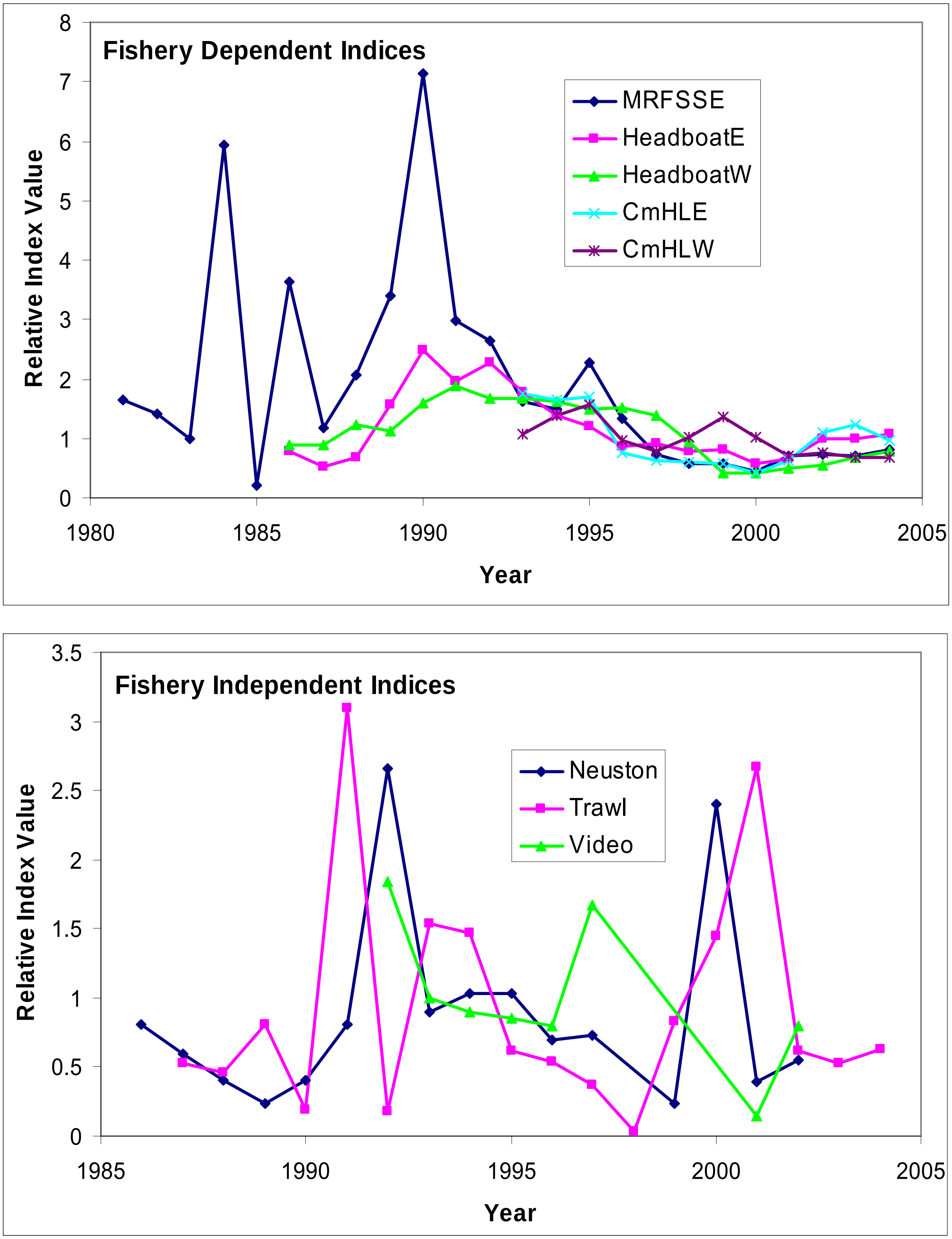
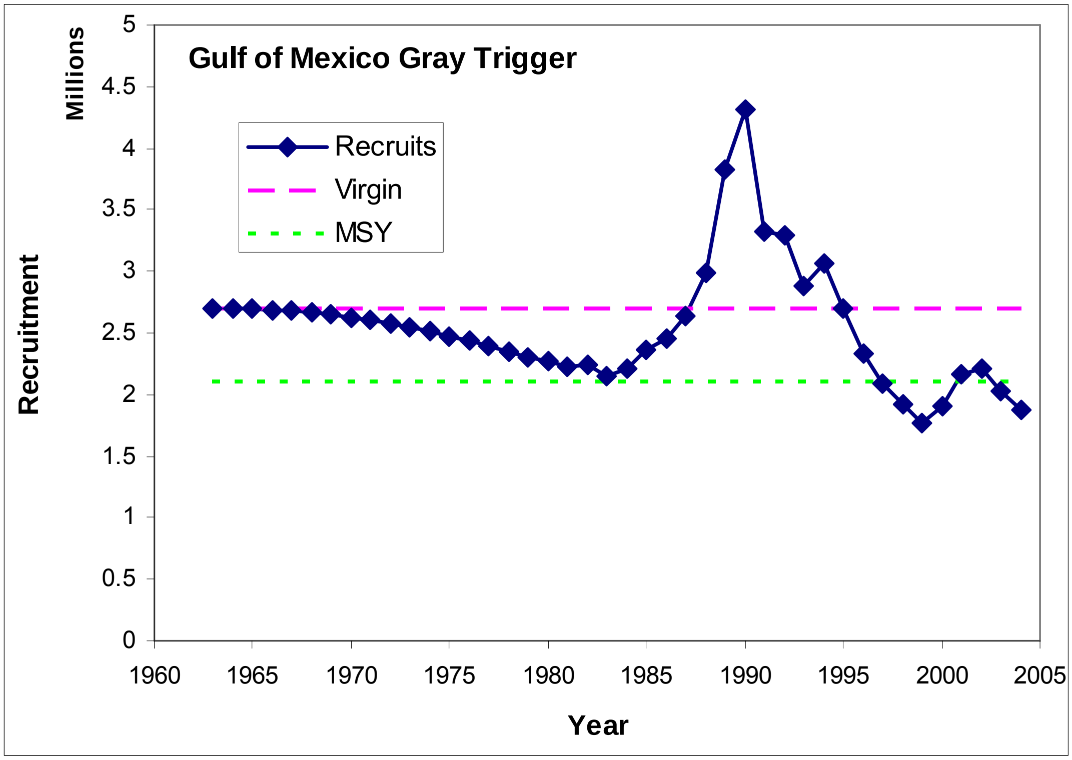


FIG. 9—Gulf of Mexico Gray Triggerfish Indices of Abundance
(a) Fishery-independent and (b) fishery-dependent indices of abundance. Normalized across the years where all indices were calculated (1992-97, 2001-02 for FI; 1993-2004 for FD).



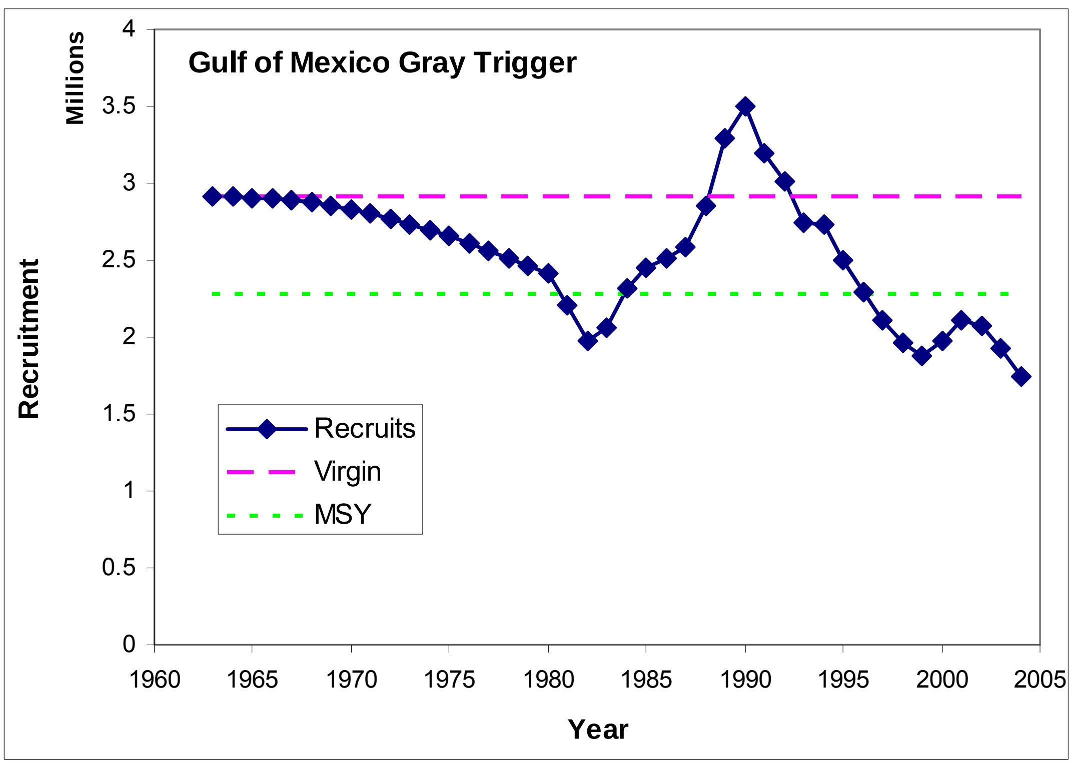


FIG. 10—Recruitment Trajectory
(a) Large Deviations (= 2), (b) Small Deviations (= 0.05).

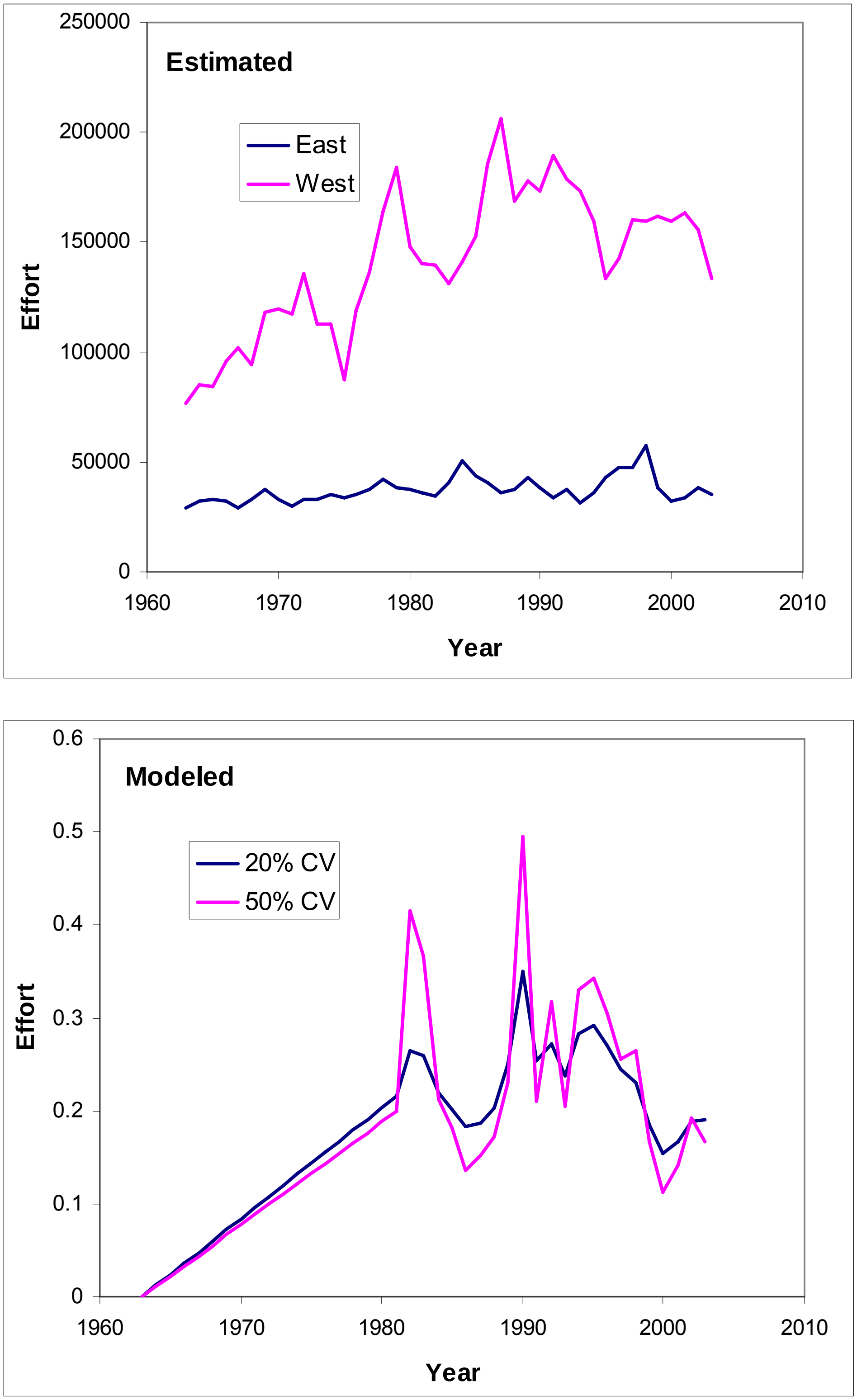


FIG. 11—Shrimp Effort Deviations
(a) Estimated values, (b) modeled values.

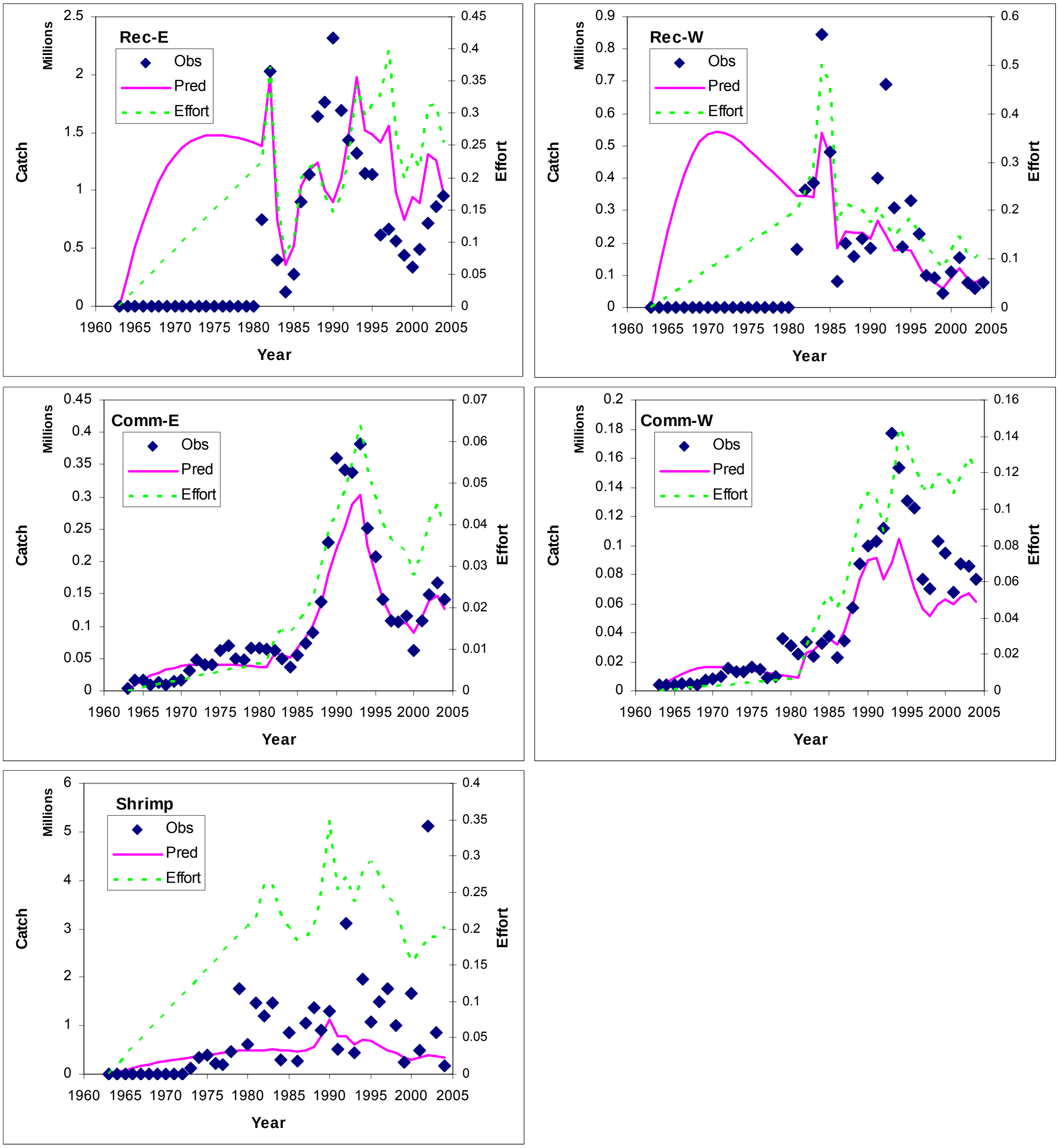


FIG. 12—Base Run Catch Fits

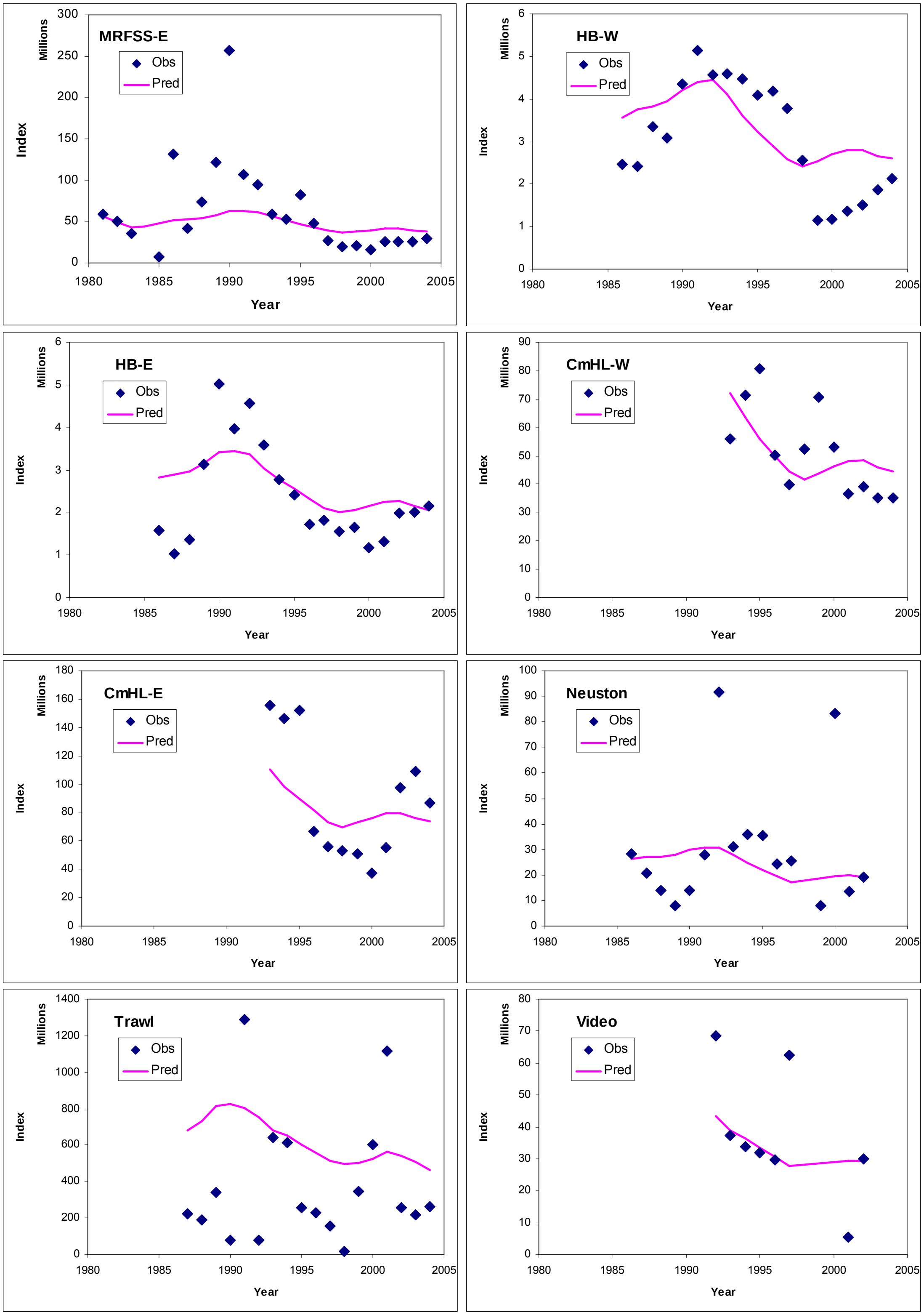
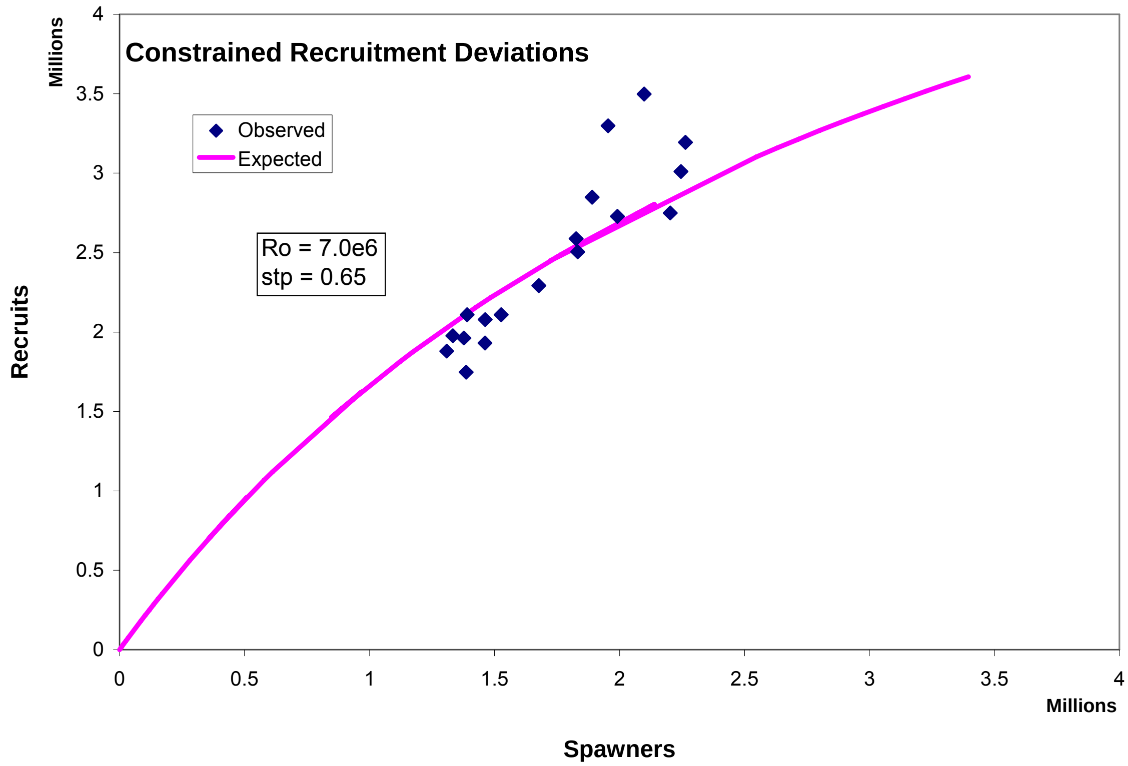


FIG. 13—Base Run Index Fits



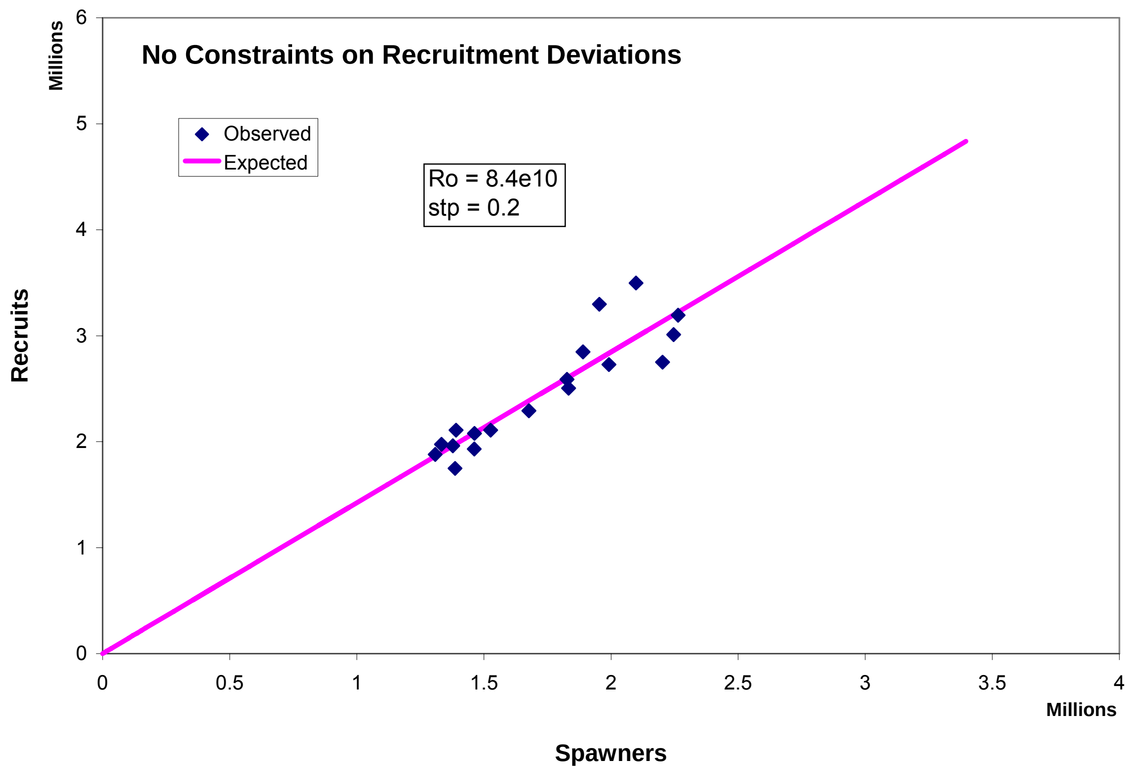


FIG. 14—Gray Triggerfish Stock Recruitment Relationships.
All based on recruitment patterns since 1986. (a) Base run with constraints on recruitment deviations as described in the text. (b) No constraints on the size of recruitment deviations.

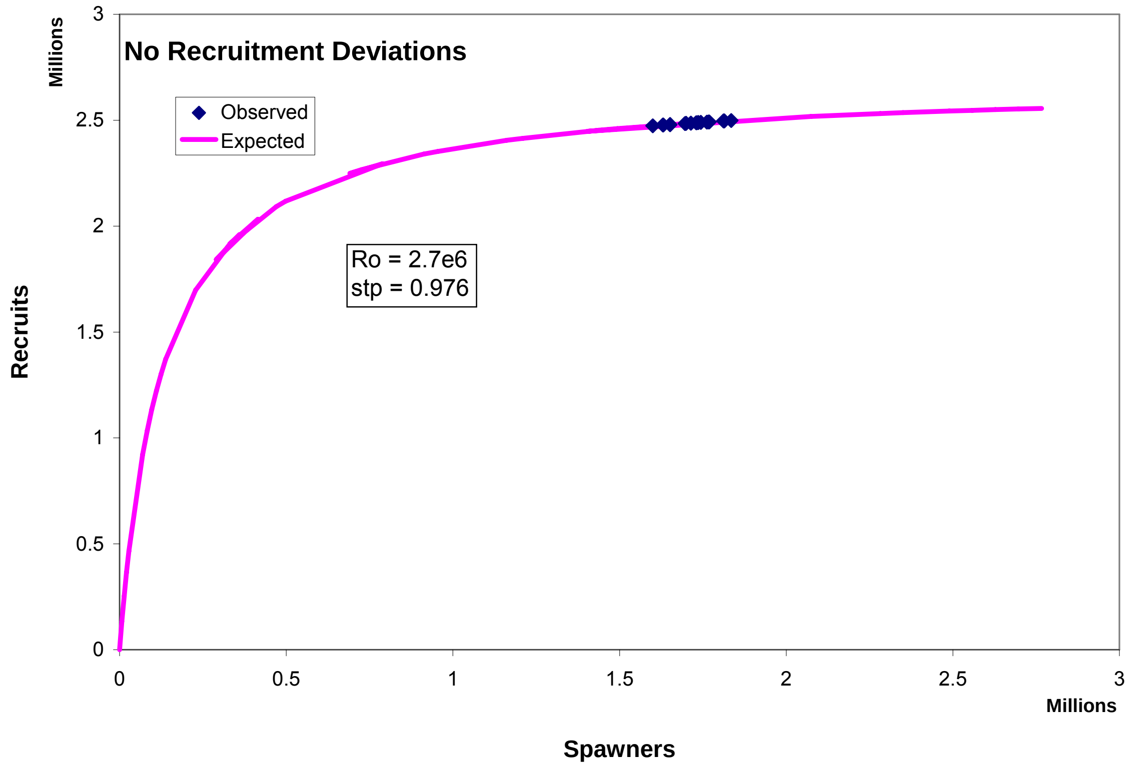
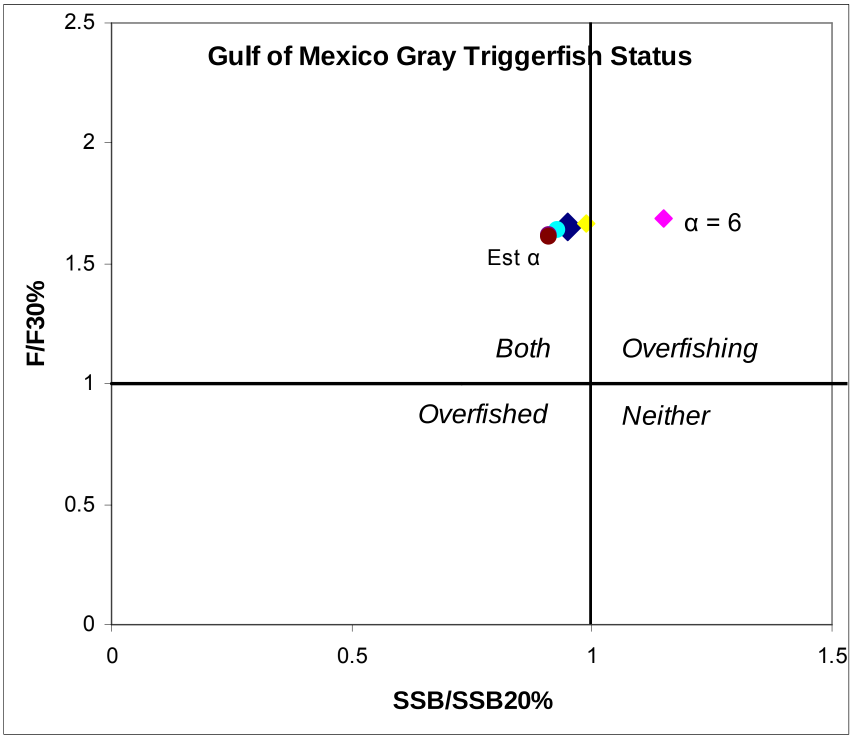


FIG. 14 (cont.)—Gray Triggerfish Stock Recruitment Relationships Under Various Scenarios. All based on recruitment patterns since 1986. (c) No recruitment deviations allowed.



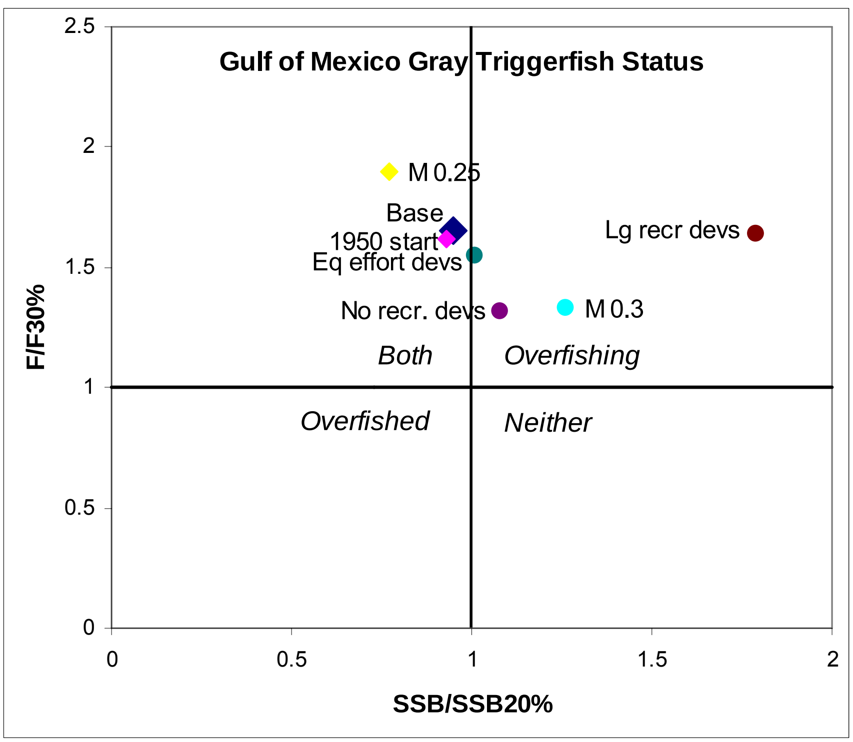


FIG. 15—Gray Triggerfish Status Relative to SPR
(a) Across steepness values; (b) across sensitivity trials.

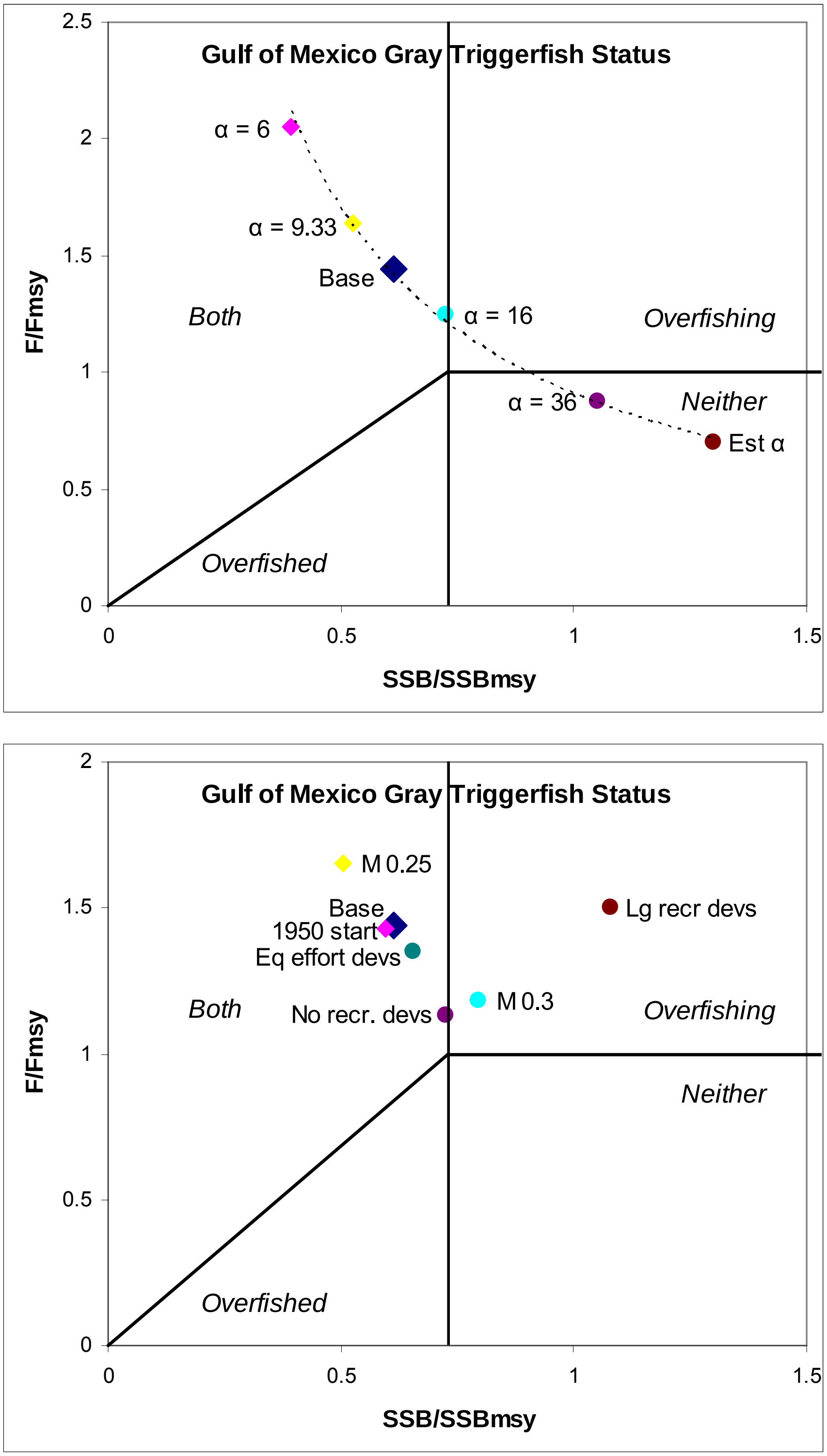
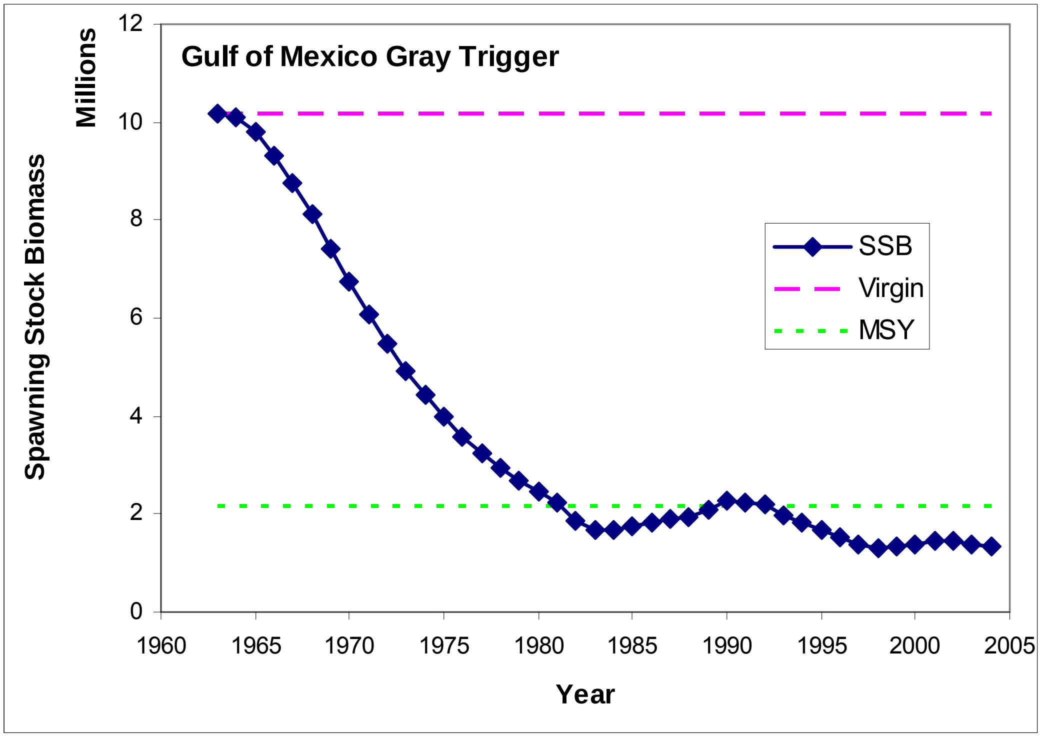


FIG. 16—Gray Triggerfish Status Relative to MSY
(a) Across steepness values; (b) across sensitivity trials.



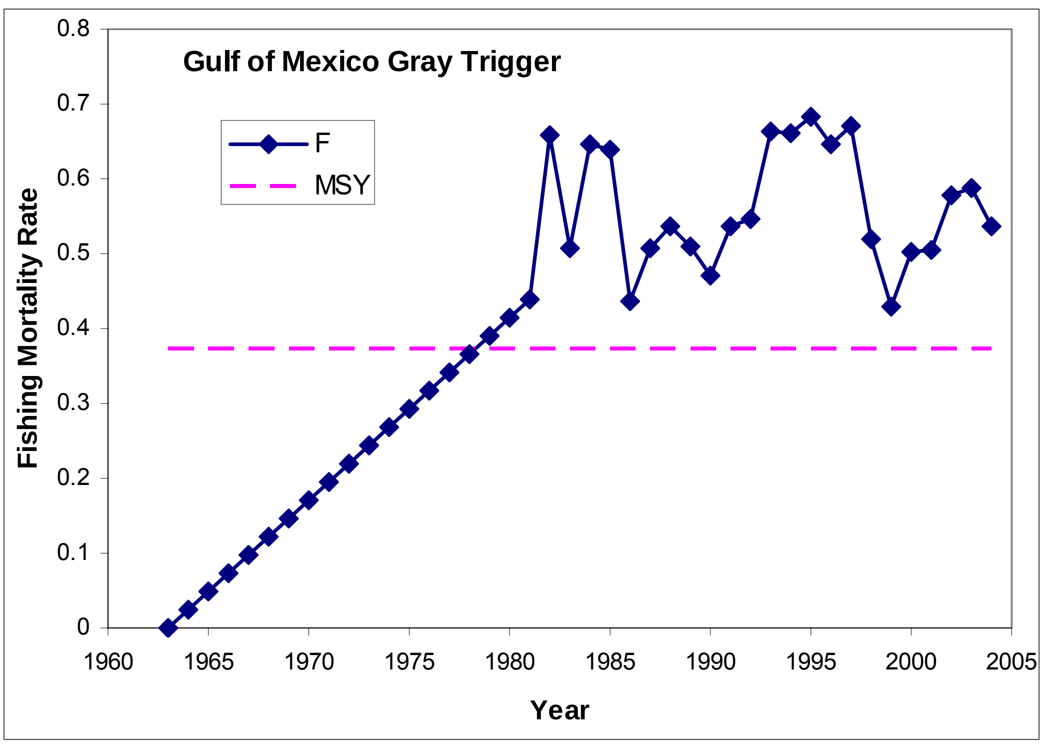


FIG. 17—Gray Triggerfish Status in 2004
(a) Spawning stock biomass (overfished); (b) Fishing mortality rate (overfishing).

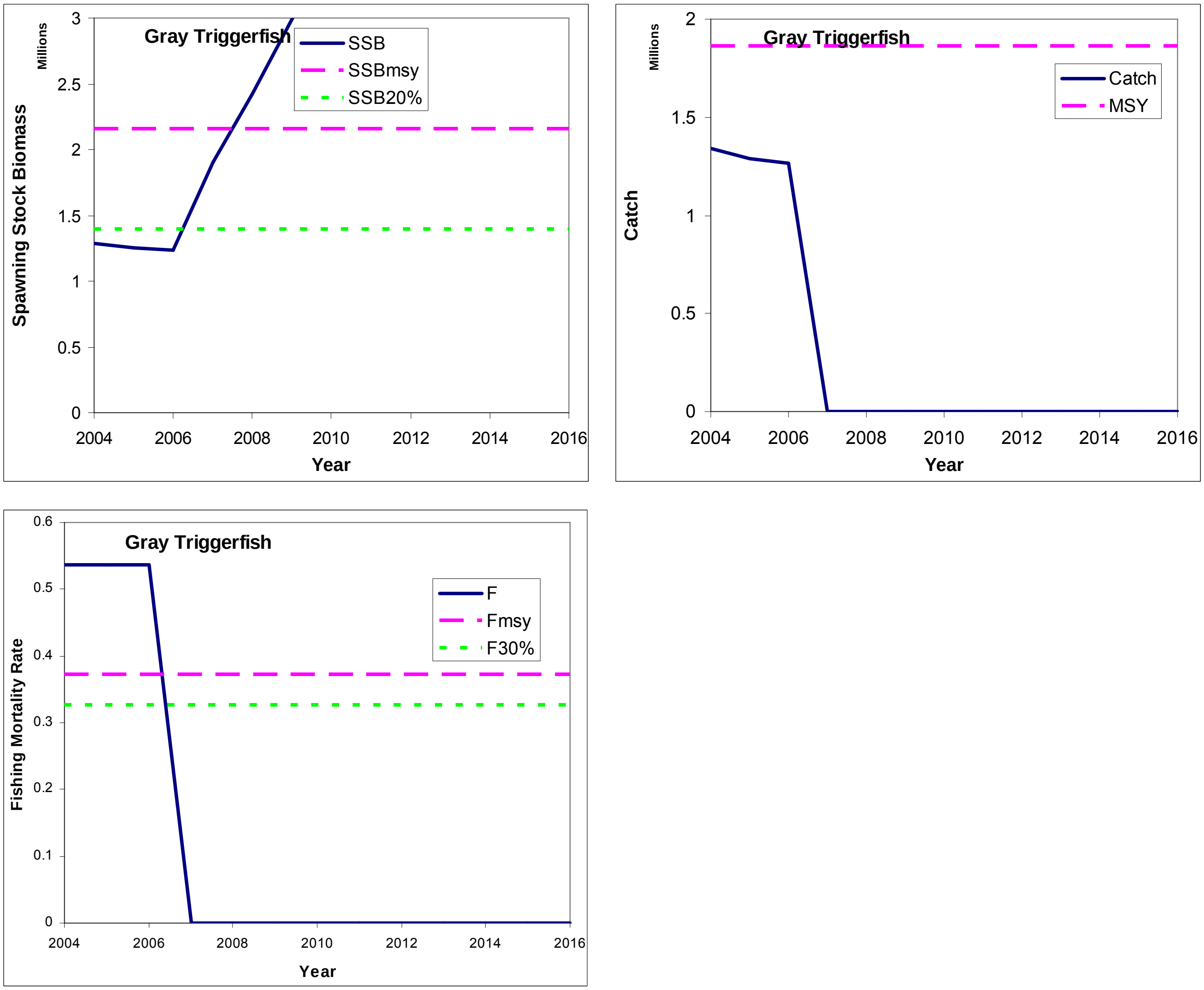


FIG. 18—Projections Under No Fishing
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

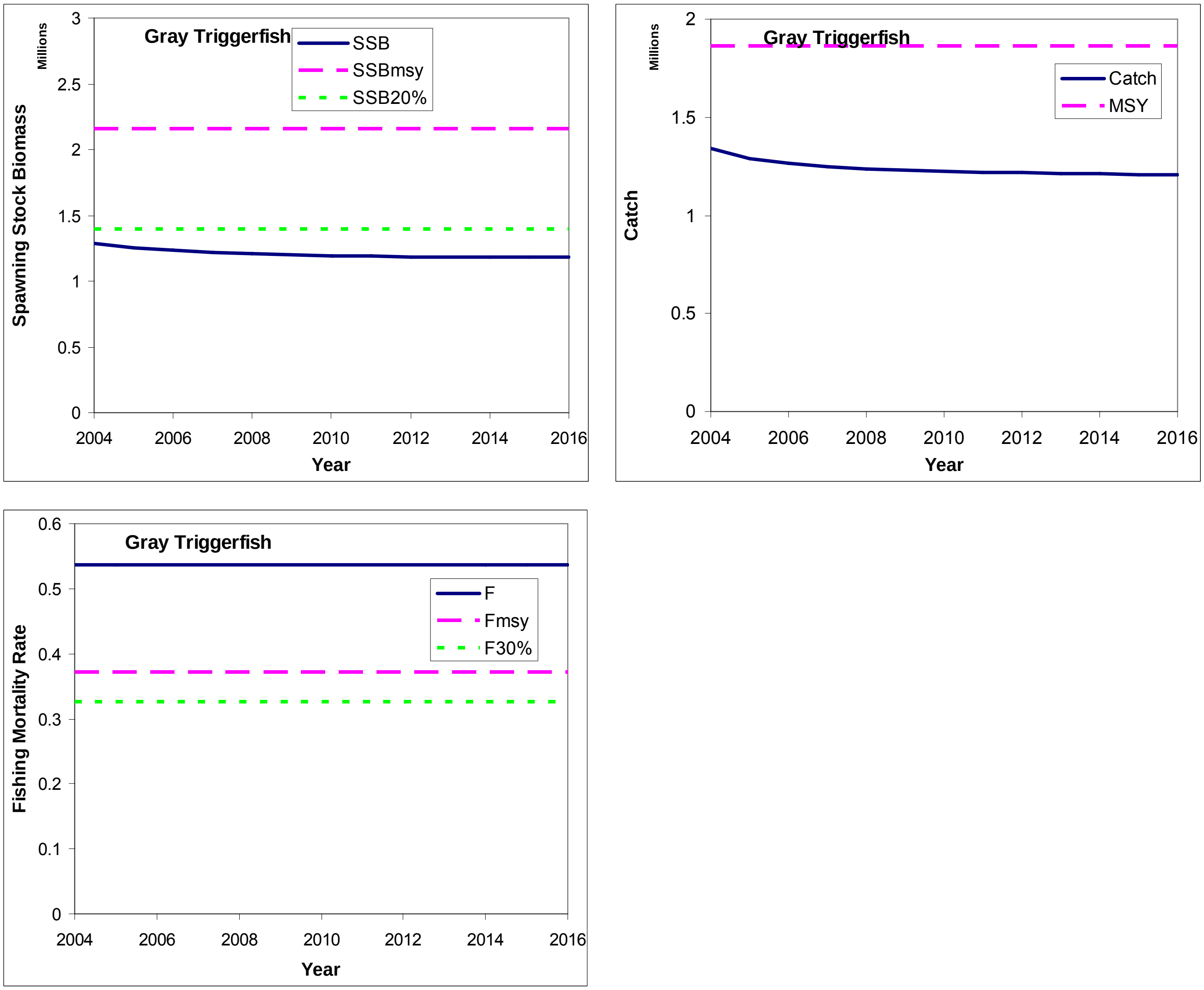


FIG. 19—Projections Under Current F (2004)
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

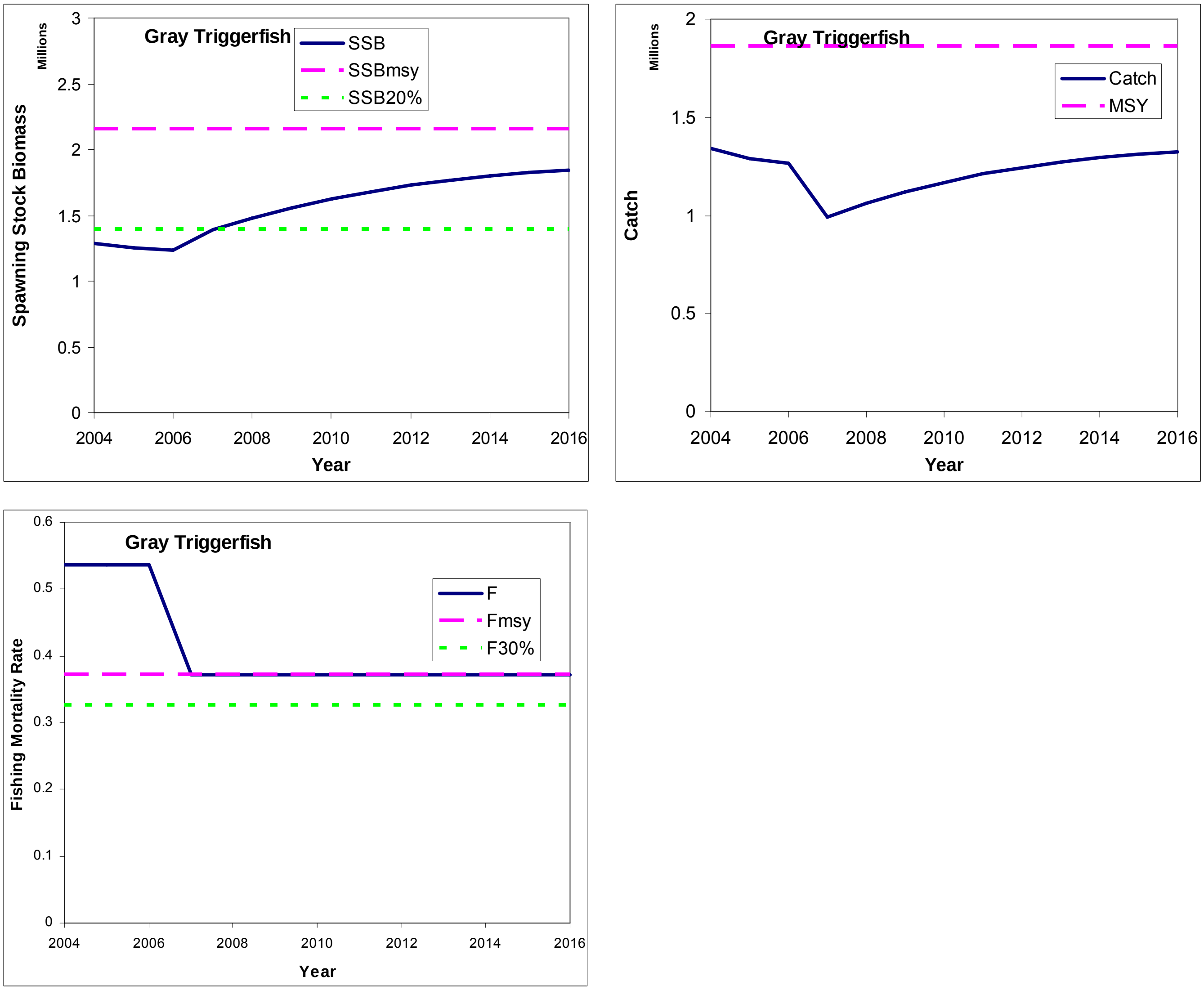


FIG. 20—Projections Under F_{MSY}
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

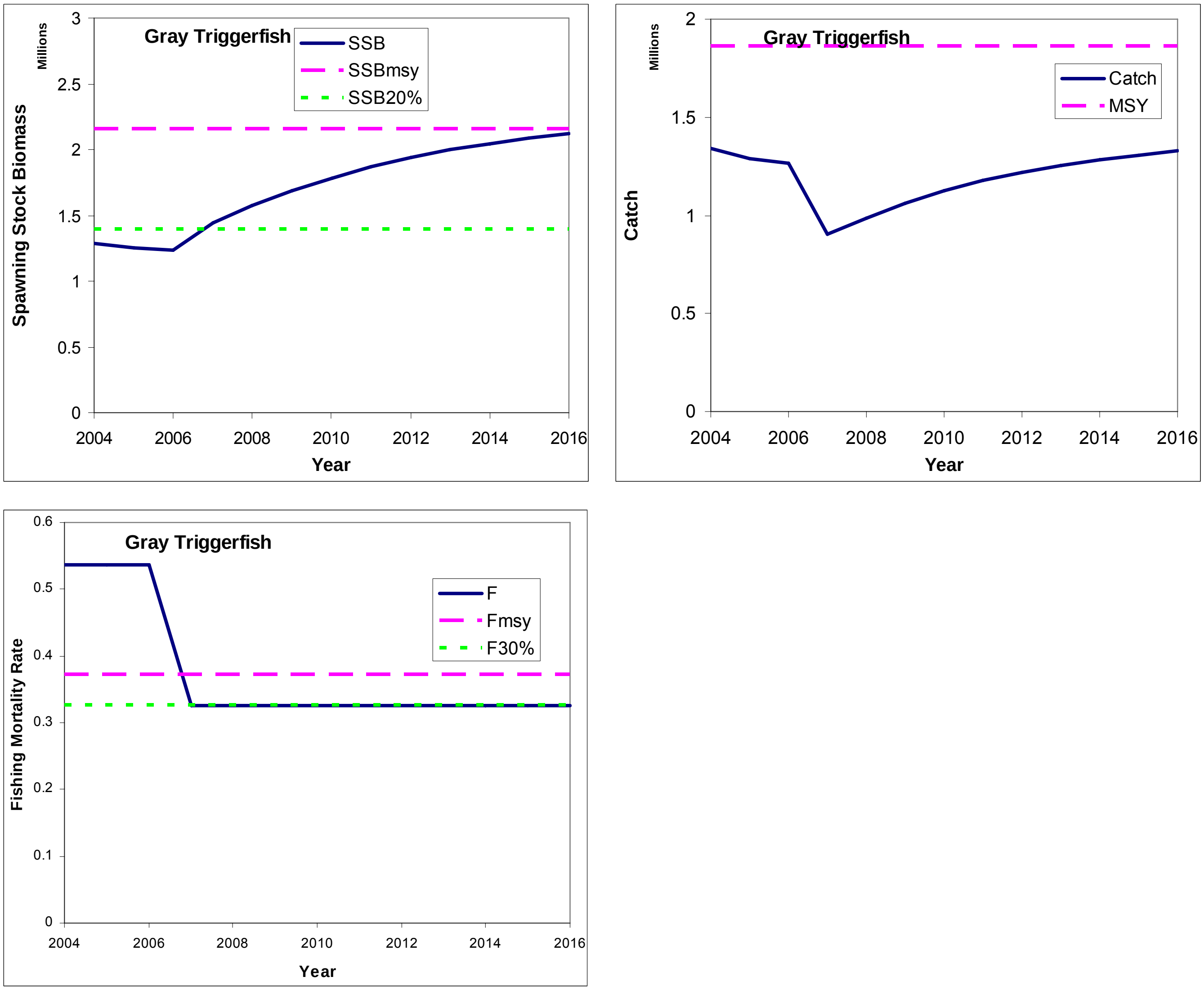


FIG. 21—Projections Under $F_{30\%SPR}$
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

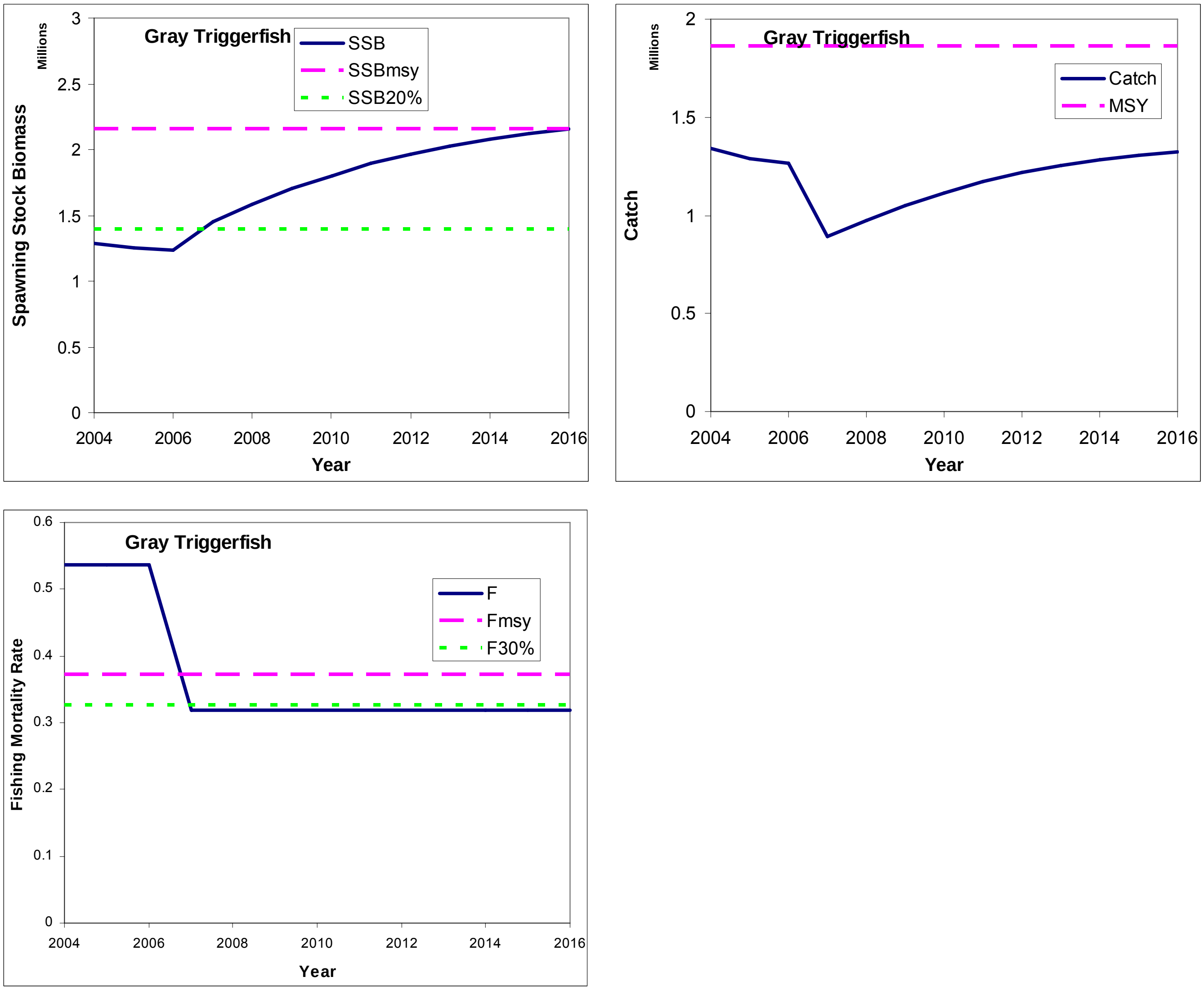


FIG. 22—Projections Under Minimum F Required to Rebuild by 2016
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.

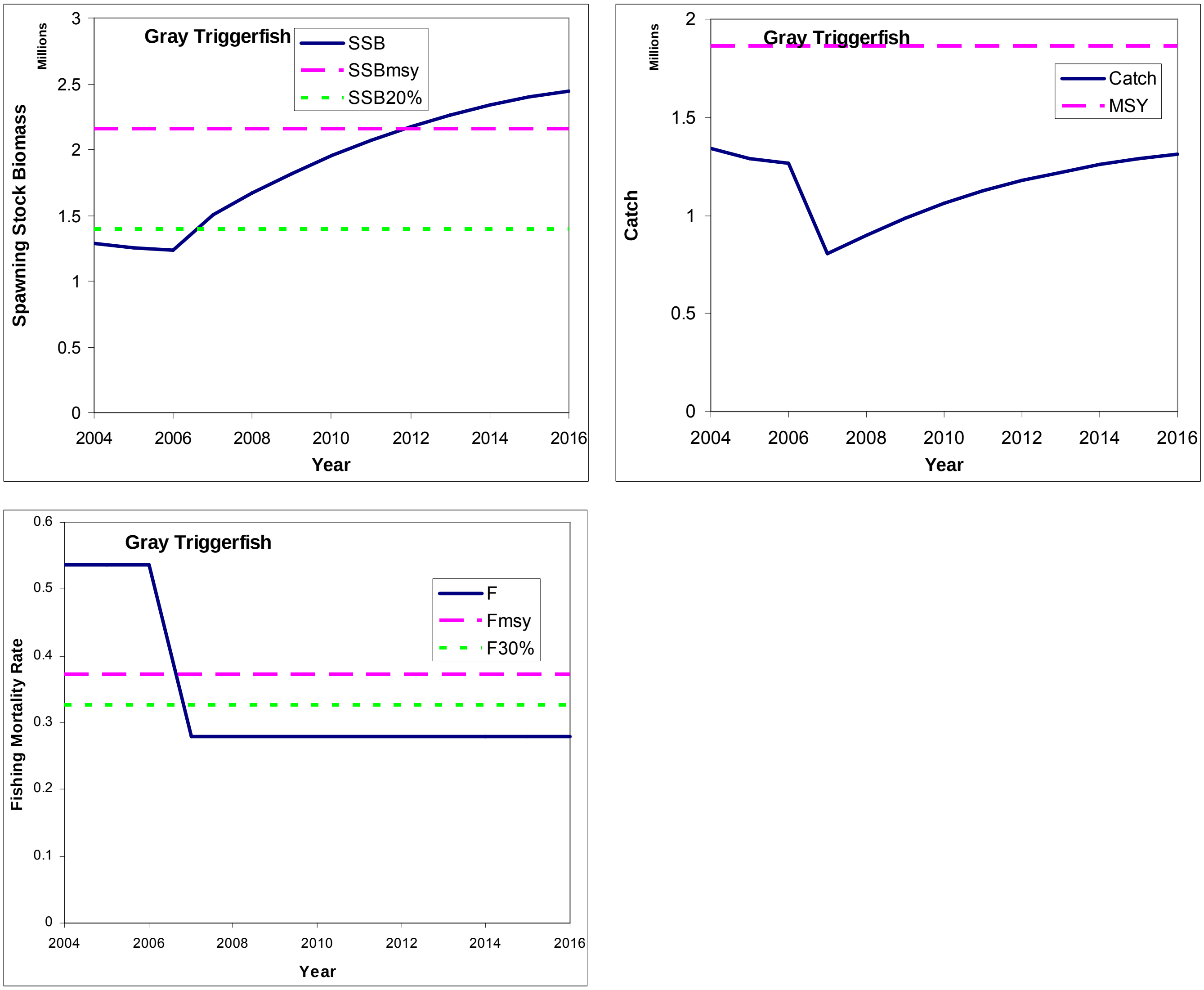


FIG. 23—Projections Under F_{OY}
(a) Spawning stock biomass; (b) Allowable catch; (c) Fishing mortality rate.